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INTRODUCTION  
TO  
THE STUDY OF MINERALS  
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L. FLETCHER.

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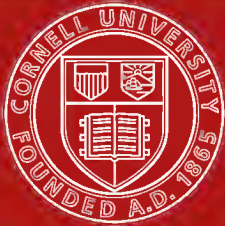
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A guide to the mineral gallery of the Br



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A GUIDE  
TO THE  
MINERAL GALLERY  
OF THE  
BRITISH MUSEUM (NATURAL HISTORY),  
CROMWELL ROAD, SOUTH KENSINGTON.  
WITH AN INTRODUCTION  
TO  
THE STUDY OF MINERALS.

PRINTED BY ORDER OF THE TRUSTEES.

1885.

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STAMFORD STREET AND CHARING CROSS.



## MINERAL GALLERY.



It is recommended that the Collections be studied in the following order :

I. THE INTRODUCTION TO THE STUDY OF MINERALS, in the first window-case on the left-hand side of the Gallery (pages 17-60).

II. THE CHARACTERS OF MINERALS, illustrated in the three succeeding window-cases (pages 61-69).

III. THE SPECIES AND VARIETIES OF MINERALS, in the forty-two table-cases of the Gallery (pages 73-113).

IV. THE INTRODUCTION TO THE STUDY OF METEORITES, in the Pavilion at the end of the Gallery (see the special Guide).

V. THE CRYSTALS, MODELS OF CRYSTALS, AND PSEUDOMORPHS, in fifteen of the remaining window-cases (pages 70-72).

VI. THE ROCKS, in the wall-cases.



To find the position in the Gallery of any of the more common and interesting minerals, the visitor should refer to the Index (page 116), where references are given to the table-case in which specimens of the mineral are placed, and to the page upon which the mineral is mentioned in the Guide.

For the use of the student there is published a separate and complete Index to the names and synonyms of all the mineral species and varieties represented in the Collection.



## P R E F A C E.

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EVERY visitor to a Natural History Museum can trace a likeness between the Animals and Plants shown there and those with which he is already familiar, and he is thus ready to derive pleasure and instruction from their examination.

But when he comes to the Minerals, and finds that with life and organised structure has apparently disappeared everything which gives separateness to the individual, and that hardly any distinctive character seems to be left save colour, he becomes impressed with the idea that, while their beauty is evident, minerals must fail of being discriminated unless we penetrate beyond their superficial aspects.

An attempt is made in the present Guide to facilitate the comprehension of the subject by "An Introduction to the Study of Minerals." It is there sought to give a statement of the more important discoveries, upon which the Science of Mineralogy is based, in such a form as to be intelligible to those who have hitherto given no attention to the wonders of the Mineral Kingdom, and at the same time to be of service to the student by indicating relations between mineral characters which might otherwise escape attention.

In addition to the specimens and models selected to make clear the statements and the reasoning of the Introduction, others have been arranged in the window-cases of the Gallery to illustrate in detail the various characters of minerals.

It may be added that in the description of the minerals of the General Collection the matter interesting or intelligible only to the student has been printed in smaller type, and thus need not perplex the general public.

*June 18th, 1884.*

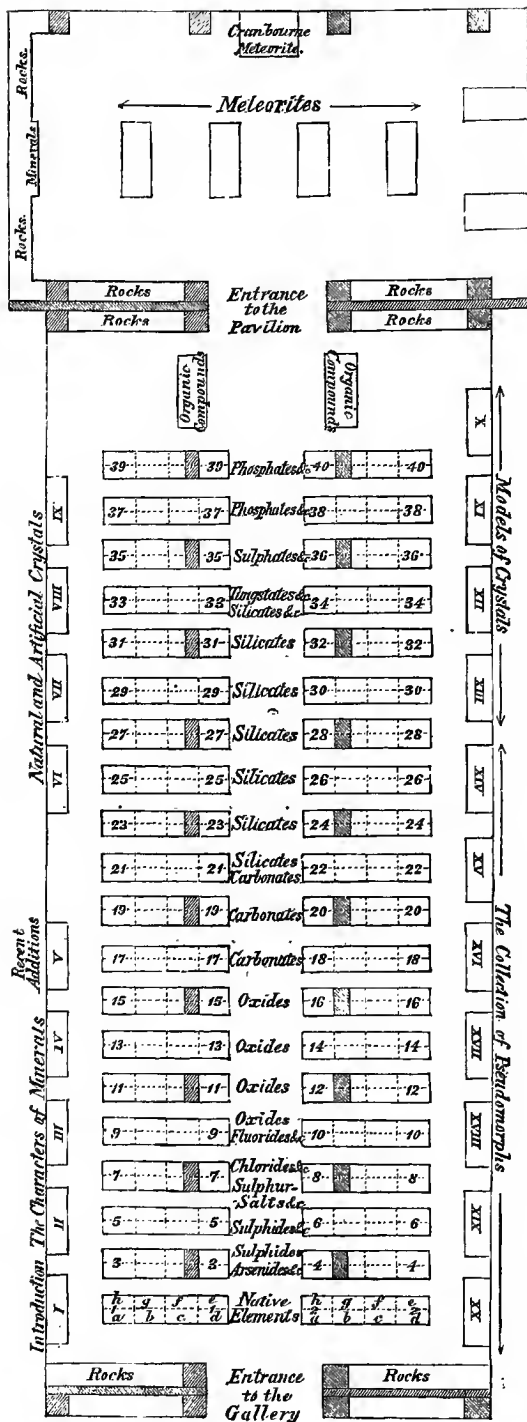
L. FLETCHER.



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# PLAN OF THE MINERAL GALLERY



## THE GENERAL ARRANGEMENT OF THE COLLECTIONS.

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By ascending the large staircase opposite to the Grand Entrance and turning to the right, the visitor will reach a corridor leading to the Department of Minerals.

In a wall-case of the corridor, to the left of the entrance to the Gallery, are shown polished specimens of some of the rocks and simple minerals used for decorative purposes.

Leaving the corridor the visitor will find the collections arranged in two rooms; the first of them, the Gallery, measuring 236 feet by 50 feet, the other, the Pavilion, 37 feet by 60 feet.

The AUXILIARY COLLECTIONS are arranged in twenty table-cases placed before the windows of the Gallery. Beginning with the first on the left, the contents of these cases are as follows:—

- I. A series of specimens and models illustrating the gradual development of the Science of Mineralogy (page 17).
- II.-IV. Specimens illustrating the characters of minerals, and the terms used in their description (page 61).
- V. Recent additions (page 70).
- VI.-IX. Crystals, natural and artificial (page 70).
- X.-XIII. Models of Crystals (page 70).
- XIV.-XX. Pseudomorphs (page 71).

The SPECIES AND VARIETIES OF MINERALS are arranged in the remaining table-cases of the Gallery, forty-two in number (page 73).

The ROCKS are shown in the wall-cases of the Gallery and Pavilion, but are not yet finally arranged.

The METEORITES are exhibited in the four central cases of the Pavilion (see the special Guide).

## THE HISTORY OF THE COLLECTIONS.

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THE Minerals formed a very small part of Sir Hans Sloane's collections, of which the acquisition by the nation in 1753 led to the establishment of the British Museum. Consisting, as the mineral portion did, chiefly of wrought articles of agate, jasper and rock-crystal, it failed to represent the variety, the natural forms, or the modes of occurrence of the products belonging to the Mineral Kingdom. Of these wrought articles, such as are interesting rather for the workmanship bestowed upon them than for the material of which they are made, are deposited at the British Museum (Bloomsbury); most of the remainder are shown in the table-cases of the Gallery.

Through the bequest in 1799 of the collection of very select minerals formed by the Rev. Clayton Mordaunt Cracherode, and the purchase in 1810 of the large collection made by Colonel Greville, including unique specimens of Rubellite, Cromfordite and Matlockite, the Minerals began to form an important part of the Natural History Collections of the British Museum.

In 1823 they were considerably increased by the presentation of a series of specimens from the Harz district by His Majesty King George IV., the silver-yielding minerals being particularly fine.

During the succeeding years many specimens which had belonged to the private collections of Mr. Heuland and Lady Aylesford were purchased for the Trustees, and at the death of Lady Aylesford the remainder of her minerals, and a catalogue of the complete collection, came to the Trustees by bequest.

By 1857 the Minerals had become so important a feature of the Museum that a special department, distinct from that of Geology, was instituted, and placed under the Keepership of Mr. Story-Maskelyne, Professor of Mineralogy in the



University of Oxford. During his term of office, which lasted nearly a quarter of a century, the Trustees were enabled by timely purchases to raise the collection to its present position, and to impart to it a perhaps unrivalled excellence as well in its general completeness as in the perfection of individual specimens.

The most important additions during this period were the Allan-Greg and the Kokscharow Collections. The first of these had been originally formed by Mr. Robert Allan of Edinburgh, and catalogued by the distinguished mineralogist Haidinger himself; additions were made to it by the subsequent owner, Mr. Robert Greg, from whom it was purchased by the Trustees in 1859. It supplied many species previously wanting, and was especially valuable for the authenticity of the localities assigned to the specimens, in which respect the Museum Collection had at that time fallen much in arrear. Its acquisition gave a new starting point for the Collection of Meteorites by the addition of a carefully formed series of those bodies; this has since become as complete a collection as can be made.

The other collection was purchased in 1865 from the eminent Russian crystallographer, General von Kokscharow; it included a very fine series of Russian and Siberian minerals, among which were specimens of Topaz and Euclase of the greatest rarity.

The collection formed by Dr. Benjamin Bright of Bristol, presented to the Trustees in 1873, furnished many additional good specimens.

Of other remarkable specimens presented to the Trustees for the National Collection we may specially mention:—

The large mass of Meteoric Iron from Otumpa, presented in 1826 by **Sir Woodbine Parish, F.R.S.**

The jade tortoise, brought from India by Lieut.-General Kyd, and presented in 1830 by **Thomas Wilkinson, Esq.** (page 100).

Several unusually fine specimens, presented in 1836 by **Richard Simmons, Esq., F.R.S.**, including specimens of Native Gold (Case 1d), Cerussite (Case 18c), Idocrase (Case 25e), Beryl (Case 30a) and Mimetesite (Case 40g).

A series of minerals from Greenland, including fine

*History of the Collections.*

- specimens of Columbite (Case 34g), presented in 1855 by **Joseph Walter Tayler, Esq., F.G.S.**
- The Parnallee and Nellore Meteorites, presented in 1858 and 1862 respectively by **Sir William Denison, K.C.B., Governor of Madras.**
- A fine specimen of Cerussite (Case 18c), presented in 1859 by **John Taylor, Esq., F.R.S.**
- A fine series of Apophyllites and Stilbites from India, presented in 1860 by **James J. Berkley, Esq.**; most of the specimens are arranged in a wall-case of the Pavilion.
- Meteorites from Durala, Dhurmsala, Shalka, Bustee, Mouza Khoorna and Udipi, presented (1861-9) by the **Secretary of State for India in Council.**
- Meteorites from many Indian localities, presented (1861-2) by the **Asiatic Society of Bengal.**
- The Cranbourne Meteorite, presented in 1862 by **James Bruce, Esq.**
- A beautiful specimen of Rubellite from Ava (Case 33a), presented in 1869 by **C. S. J. L. Guthrie, Esq.**
- A magnificent specimen of Proustite, the light-red silver ore (Case 8b), presented in 1876 by **Henry Ludlam, Esq., F.G.S.**
- A meteorite from Japan, presented in 1883 by **Naotaro Nabeshima, Esq.**
- During the last forty years specimens have been frequently presented by **William Garrow Lettsom, Esq.,** and **Professor John Ruskin**: among those given by Mr. Lettsom may be noted the nearly unique specimen of Whewellite (Case 39h), the Epidotes from Traversella (Case 27d), and the Apatite from New York (Case 40b); and, among those given by Prof. Ruskin, the pink crystals of Fluor from Switzerland (Case 7g), the long branch of Native Copper placed in the lower part of Case 1, and many specimens of Native Silica shown in a table-case of the Pavilion.

## THE SCOPE OF A COMPLETE MINERAL COLLECTION.



A Mineral collection, in order to be complete, must aim at presenting all the definite varieties of chemical composition of the distinct mineral substances which occur in the Earth's crust, and at the same time must illustrate the often very extensive varieties of crystalline form assumed by the minerals of a species or group. But besides these chemical and morphological features other important characters have to be illustrated, among which are the various modes of occurrence of each particular mineral, including its associations with other minerals; and in a great national collection that is to illustrate the mineralogy of the world, it is important that there be specimens from all localities where a mineral occurs under special and noteworthy circumstances; and it must be a special object that examples of each mineral species should show its most complete development, whether in magnitude or perfection of crystals, in the colour and limpid purity, or in any other important quality which may belong to it in its more exceptional occurrence.

In a mineral collection formed and arranged with these purposes in view, will be found materials of the greatest interest for science, and alike for the useful and ornamental arts: to the crystallographer, it offers some of the best illustrations of a most beautiful geometrical science; to the physicist, it provides the material on which some of the most refined and important investigations have been and may be made in connection with the theories of light, heat, magnetism and electricity; and to the geologist, its petrological department presents the means for discriminating those minerals, of which, though they are often only recognisable under the microscope, the largest portion of the Earth's crust is formed.

Here will be found, in all their variety, beauty and association, the minerals which, under the name of *ores*, furnish the metals so essential to the needs and happiness of man; here also are specimens of the numerous minerals which, whether immediately or as the sources from which manufacturers derive important products, are employed in the multifarious purposes of daily life. The suggestion that materials for construction and architectural ornament, for pigments, mordants and bleaching processes, that the phosphates for manures, the alkalies, and the materials for the manufacture of acids, are all largely dependent on the mineral resources of the world, will sufficiently show how intimately a complete mineral collection is connected with the arts and with commerce.

An illustration of the importance of a single mineral is afforded by Calcite or carbonate of lime. As the almost ubiquitous limestone, it supplies in some of its varieties the building materials of our cities; and when burnt gives quicklime, and in some of its impurer forms hydraulic cement; while in other varieties it presents itself as the white and spotless material used for statuary marble; or, again, beautifully and finely coloured, forms the infinitely varied ornamental marbles; sometimes it appears as calcspar in a thousand crystalline forms, which it takes the skill of a crystallographer to reduce to a common symmetry; or, again, as in one locality in Iceland, it occurs in large masses of limpid crystal conspicuous for its double refraction, a character which rendered it invaluable in the hands of Bartholinus, Huyghens and Fresnel, for the investigation of the properties of light; or, again, in its softer form of chalk, it subserves many a domestic use.

Here also are to be found rough and cut specimens of the precious stones, among which may be mentioned the Diamond, a crystallised form of the element carbon; the Balas ruby and the Spinel ruby, a compound of alumina and magnesia; the Chrysoberyl and Alexandrite, a combination of alumina and beryllia; the Sapphire and Ruby, the sesquioxide of aluminium; the Hyacinth and Jargoon, a compound of silica and zirconia; the Amethyst, Sard, Plasma, Prase, Chalcedony and Noble Opal, varieties of silica; the Chrysolite and Peridot, a silicate of magnesium and iron; the Garnet with a varied

composition; the Beryl, Emerald and Euclase, compound silicates of aluminium and beryllium; the Tourmaline and Rubellite, a borosilicate of several bases; the Lapis-Lazuli, a compound silicate and sulphate; and the Turquoise, a hydrated phosphate of aluminium.

Petrology, so far as it is a classificatory science, it is essentially the function of a mineralogist to study and illustrate. The interest presented by a rock is not merely dependent upon its chemical composition, though that is a fundamental principle in describing it, nor upon its being a compact aggregation of the various minerals among which the chemical ingredients are distributed; but it is also historical, since the rock has assumed the form, in which we observe it, at some earlier period of geological time. To trace that history, and to collocate the various rocks of the globe in their relative positions and historical sequence, and to make each rock contribute its evidence towards the building up of that history, is the part of the geologist. But it falls entirely to the mineralogist to collect, describe and classify the almost numberless varieties of rock with which the geologist has to deal.

And to describe a rock with accuracy is perhaps the most difficult task that the mineralogist has to perform. It is possible to make a complete chemical analysis of the whole of a rock-fragment, but the cases in which the individual minerals that compose the fragment can be isolated and separately analysed are extremely rare. The microscope, however, has been called in to raise the power of human introspection; under that instrument not only are the mineral ingredients of a thin slice of a rock—so thin as to be perfectly transparent—rendered visible, but the action of each separate ingredient upon the transmitted light can be easily ascertained. By combining the instruction gained from the chemical analysis of rock-fragments with the results of such a microscopic study, the mineralogist, after a long and intimate experience, is enabled to speak, with at least an approximate certainty, of the characters and even the chemical composition of the various constituent minerals of each kind of rock.

The great divisions of a petrological series are readily marked out, though their precise boundaries are not always

so easy to define. We have, for instance, the sedimentary rocks, sometimes composed largely of a single ingredient, as the sandstones and limestones, at other times less simple in their nature, as the clays, shales and slates. Again, we have the igneous rocks, comprising, on the one hand, lavas and beds of ash and pumice that have been poured out or ejected from orifices in the Earth's crust, and, on the other hand, the more compact forms which have cooled from a condition of fusion, or semi-fusion, under the pressure of superincumbent strata. Again, there are rocks of an intermediate character, in which a sedimentary deposit has become metamorphosed in the course of time under the combined influences of pressure and temperature.

Nor from the list of the interesting contributions of a mineral collection should be omitted the series of meteoric bodies which have come to this Earth from the regions of space. These strange masses of metallic iron, more or less rich in nickel, or of stone impregnated with the same metallic material, serve as witnesses that the same laws of chemical combination and of crystallographic symmetry, and the same elements, of which our own world is built up, pervade the regions of space through which these masses of matter have wandered swiftly till, entangled in our atmosphere, they have been arrested in their career and have fallen to the Earth with startling accompaniments of explosion, fusion, and dissipation of their material, as a consequence of the enormous temperature for which they have exchanged an often more than planetary velocity.



# AN INTRODUCTION

TO THE

## STUDY OF MINERALS.

*The specimens and models illustrative of this Introduction are arranged in the first window-case on the left-hand side of the Gallery.*

**1. THE** material products of Nature are assigned to three Kingdoms,—the Animal, the Vegetal and the Mineral; the distinguishing character of the products belonging to the two former being the presence of organs essential to the existence and growth of the individual.

Specimen  
of fluor.

The distinction, however, is not always very obvious, for in some cases the outer form of a mineral product is so like that of a plant that it misleads the ordinary observer.

Specimens  
of  
pyrolusite  
and  
moss-agate.

**2.** The Mineral Kingdom includes not only the unorganised products of our own Earth, but also those which belong to outer space: some knowledge of the latter has been gained directly by examination of the bodies called METEORITES which have fallen from the sky; and also, indirectly, by a study of the light which reaches us from the sun, the stars and the comets. These investigations have not yet indicated the existence of life outside our own planet.

Specimen.

**3.** It is practically possible to obtain a direct knowledge of the mineral products of our own Earth within only a mile or so from its surface; but the consideration of even this limited amount of matter is far too vast for one individual or one science.

The present arrangement into hill and dale, river and sea is accordingly left to Geography, and the historical aspect of the

materials to Geology; the Mineralogist deals, not with the arrangement past or present, but with the nature of the matter itself; he determines as far as possible all its characters, and thence deduces principles on which to classify the various kinds.

Soil. 4. The first mineral product met with in the examination of the solid portion of the Earth is usually a loose *Soil*, which on inspection is found to be a mixture of fragments of substances of different kinds, and to have resulted from the wearing away of the more compact matter in the neighbourhood. Specimen.

Rock. 5. Beneath the loose soil is a firmer material, retaining much the same character generally over a considerable area of country and sometimes for a considerable depth; to such a material the term *Rock* is applied. Specimen of mica-schist.

Rocks are generally composite. As in soil, so also in most kinds of rock the unaided eye is able to detect different kinds of matter. Specimen.

The illustrative specimen in the case is a fragment of the rock called Granite; mere inspection teaches us that in this specimen at least three different kinds of matter come together—first, a substance of a light brown colour, with some of its surfaces quite smooth and plane (Felspar); secondly, a glassy substance of a milky colour and irregular shape (Quartz); and, thirdly, a dark-coloured substance apparently made up of thin leaves (Mica). By a process of mechanical division we can thus extract from this kind of rock at least three substances; and these will prove to be distinct from each other, not only in outward appearance, but in all their manifold properties.

Simple minerals. 6. It will be found, however, that by no amount of *mechanical* division can any of these three substances be reduced to others having different characters; they are therefore called **SIMPLE MINERALS**, or, more briefly, **Minerals**. Specimens

Other rocks. 7. The composite character of some rocks is less evident to the naked eye, and requires the aid of a microscope for its demonstration. Specimen of diabase

Other rocks, as *Marble*, are of a simpler nature than the above, and consist wholly of a single kind of matter. Specimen.



Rock-forming minerals are not of many different kinds.

8. Up to the present we have had regard only to those minerals which are scattered more or less regularly throughout the whole mass of a rock, and are therefore considered to be *essential* components of it. Although such simple minerals compose the greater portion of the crust of the Earth, their kinds are extremely limited in number.

Modes of occurrence of other simple minerals.

9. But in addition to their essential components, rocks contain, either completely embedded or lining crevices and cavities, many other simple minerals, more or less irregular or local in their occurrence.

Gold, for instance, has not been found either as a rock or as an essential component of one, but it often occurs as an *accessory* constituent completely embedded in a part of a rock. From a side of the cavity of the next specimen in the case springs a beautiful mineral (Scolecite), showing no likeness to any essential component of the enclosing rock (Dolerite); and a like remark may be made with respect to the simple substance (Wavellite) which lines the sides of the two parts of the adjacent one (Sandstone). In fact, it is from rock-cavities, filled with foreign matter and constituting veins and lodes, sometimes of enormous size, that most of the mineral wealth of the world is derived.

Sometimes simple minerals are found as loose waterworn pebbles on a sea-shore or in the bed of a stream.

Fluid minerals.

10. In addition to the solid unorganised products of Nature, there are others which are liquid or gaseous at the ordinary temperature; as they are few in number and generally mixtures, with the exception of the liquid Mercury they will be left out of consideration in the following pages.

11. The existence of *simple minerals* is so elementary a fact that it must have been more or less distinctly recognised from the earliest times. But to determine the properties of each kind of simple mineral so far as to be able to assert that one specimen is of the same kind or is different from another, and to classify the various kinds, are difficulties of a very serious character. A brief sketch of the gradual development of the

Science of Mineralogy will perhaps be the most instructive mode of explaining the nature of these difficulties and the ways in which they have been met.\*

Distinction  
of minerals  
into kinds  
by the  
ancients.

12. The modern student relies so much on crystalline form and chemical composition as distinguishing characters, that he is at times almost inclined to believe that without a knowledge of these any distinction into kinds must have been impracticable; and yet, to give only a single instance, the diamond was recognised as a distinct mineral, and distinguished by a special name, quite two thousand years before its combustibility and its chemical identity with carbon had been discovered.

In the oldest existing treatise on Minerals † we are told how the subject was treated more than two thousand years ago.

Minerals were then classified as *Metals*, *Stones* and *Earths*. The class of *Metals* included, not only the metals proper, but all those minerals which are dense and have a metallic lustre; that of *Stones* contained those which are unacted upon by water, while the *Earths* were minerals which, when placed in water, either fall to pieces or are dissolved therein.

The following extract from the treatise referred to will show what were the properties then used for the distinction of "Stones" into kinds:—

"There are in Stones of different kinds many peculiar qualities; of which colour, transparency, brightness, density, hardness, tenacity and the like are frequent, though other more remarkable properties are not so common. But beside these qualities there are others; such as their acting upon other bodies, or being subject or not subject to be acted upon by them. Some are fusible, others will never liquefy in the fire; some may be calcined, others are incombustible; to which it may be added that in the action of fire on them they show also many other differences. Some, as Amber, have an attractive quality. Others serve for the trial of Metals, as the Lydian stone.

\* See also Whewell's *History of the Inductive Sciences*. London, 1857.

† *History of Stones*; written by Theophrastus shortly before 300 B.C.: English version by John Hill. London, 1746.

“But the most known and general properties of Stones are their several fitnesses for the various kinds of work. Some of them are proper for engraving on; others may be shaped by the turner’s tools; others may be cut or sawn. Some also there are which no iron instruments will touch, and others which are very difficultly, or scarcely at all, to be cut by them.”

Experiment  
necessary.

13. Among the characters mentioned above there is not a single important one, appealing directly to the sense of sight alone, which will serve for the distinction of minerals into kinds; for colour, transparency and brightness are either too common or too inconstant to be of much avail. The fact that the most important distinguishing characters require experiment for their determination, and thus cannot be learned from a mere inspection of the specimens as they lie in a table-case, is the chief reason why a collection of Minerals is so much more difficult to understand than is one of organised bodies.

Origin of  
the term  
Crystal.

14. In the course of time another important and general but less obvious character came gradually into recognition.

To a certain mineral the ancients gave the name Crystal Specimens.  
(i.e. clear ice), for, owing to its transparency, its freedom from colour, and the frequency with which it enclosed other bodies, the ancients imagined that it had been formed through the subjection of water to an intense cold. Even so lately as the year 1672 this theory of the origin of Crystal is referred to by the learned experimenter, Robert Boyle,\* in the following words:—

“I found the weight of Crystal to be to that of water of equal bulk as two and almost two-thirds to one; which, by the way, shows us how groundlessly many learned men, as well ancient as modern, make Crystal to be but ice extraordinarily hardened by a long and vehement cold, whereas ice is, bulk for bulk, lighter than water (and therefore swims upon it), and (to add that objection

\* An Essay about the Origine and Virtues of Gems; by Robert Boyle. London, 1672.

against the vulgar error) Madagascar and other countries in the Torrid zone abound with Crystal."

"Crystal" is bounded by plane surfaces. It was observed by the ancients that this mineral, wherever found, has a characteristic shape (Fig. 1). It is naturally

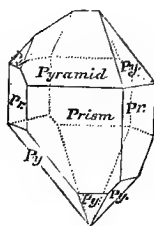


Fig. 1.

bounded by flat surfaces (or planes) arranged in a definite way—six of them forming a column (or prism), at each end of which are arranged six other planes inclined to form a pyramid. The relative sizes and the shapes of these planes vary in different specimens.

Later meaning of the term Crystal. 15. This peculiarity of being naturally bounded by flat surfaces, and not by the curved ones which are so characteristic both of Plants and Animals, was afterwards found to belong not only to "Crystal" but to other minerals both transparent and opaque; so that by an extension of its meaning the term *Crystal* was eventually used to signify, not the particular kind of mineral still known as Rock-crystal, but any mineral naturally limited by plane faces. Specimens.

Steno's discovery. 16. It was not till 1669 that any important addition to the knowledge of the properties of minerals was made. In that year Nicolaus Steno,\* a Danish physician, announced that, amid all the variations in the sizes and shapes of the faces of the mineral termed Rock-crystal, there was something constant besides the number and the grouping of the faces. Cutting each of a series of specimens in a direction at right angles to the edges of the prism, he found that the edges of the six-

\* De solido intra solidum naturaliter contento dissertationis prodromus. Florentiæ, 1669: English translation, London, 1671. Figs. 2 and 3 are reproductions of figures given by Steno.

sided sections thus obtained vary in length, and thus form figures apparently quite distinct from each other (Fig. 2).

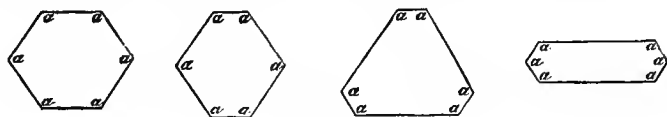


Fig. 2.

On careful examination of these figures, Steno found that although the sides vary in length they do not vary in inclination to each other; that in fact the angles of any one figure are equal both to each other and to every angle of each of the remaining figures. Again, making sections of the specimens in another direction, namely, at right angles to the edge formed by a face of a pyramid with a face of the prism, he obtained such figures as the following (Fig. 3):—

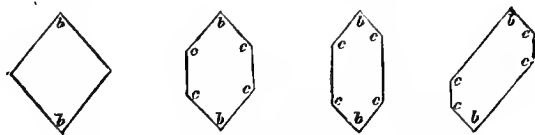


Fig. 3.

The angles of any one of these figures are not, as in the previous case, all equal to each other; two of them, the opposite and equal angles  $b$ , are different in size from the remaining four equal angles  $c$ , while both  $b$  and  $c$  are distinct in size from the angles  $a$  of the previous figures. And in the case of each of the specimens examined, Steno found that when the section was made in the stated direction he always obtained a figure having two angles equal to  $b$  and four angles equal to  $c$ , except when the absence of the prism led to a four-sided figure with two opposite angles equal to  $b$ , as shown in Fig. 3.

Hence he inferred that in all specimens of Rock-crystal corresponding pairs of faces have the same inclination.

17. A simpler method of procedure is to cut an angle in cardboard into which an angle of one of the specimens will just fit, and then to show that this is likewise the case with a corresponding angle of any other specimen.

Steno's explanation.

18. To account for this property Steno made the following suggestions :—

1. Rock-crystal has once been liquid ; as is shown by the Specimens.  
way in which it encloses other bodies.
2. Rock-crystal may increase in size ; as is proved by the Specimens.  
fact that sometimes stages in the growth are indicated by the positions of the enclosures.
3. The original nucleus, owing to the “nature of Rock-crystal,” assumed the form of a regular six-sided prism, terminated at each end by a six-sided pyramid.
4. The increase is due to the deposit of layers of matter upon the faces of the nucleus.
5. The thickness of the layer deposited upon a given face is the same in all its parts ; the outer surface will therefore still be plane and be parallel to the face upon which the layer is deposited ; hence the angles between the faces will remain constant in size during the growth.
6. The thickness of a layer, though constant for various parts of the same face, is different for different faces, owing to the variety of their positions relative to the surrounding liquid ; the faces themselves may thus vary considerably both in size and shape.

These suggestions, though on the whole satisfactory, fail to Specimen. account for the presence of faces additional to the more prominent ones already referred to ; and yet such additional faces are of common occurrence.

Crystallisation.

19. The specimens of no other mineral being so similar to each other in form as those of Rock-crystal, a whole century passed away before any extension was given to the law announced by Steno. In the meantime it was found that a natural limitation by plane faces is to be met with, not only in the Mineral Kingdom, but whenever any dissolved substance reappears in the solid state through the evaporation of the solvent ; and that when the evaporation is slow and the disturbance small, very perfect crystals are the result. Crystals Specimens. thus obtained have been termed *artificial*. It was further remarked that to some extent the shape of a crystal depends

on the kind of substance dissolved; common salt reappears as cubes, alum as octahedra, blue vitriol in rhomboidal forms, and nitre as prisms. It thus came to be imagined to be a general law of Nature that when the particles of a body are separated by a fluid and thus made free to move, they tend to arrange themselves into regular shapes, limited by plane faces, when the fluid disappears. Still, although it was recognised that the shape of a crystal depends in some way or other on the nature of the substance, it was found that the dependence was not a simple one, for, even with the same substance, very different shapes of crystal may be obtained.

Romé de  
l'Isle

**20.** To Romé de l'Isle \* belongs the great credit of discovering that these various shapes of crystals of the same natural or artificial product are all intimately related to each other.

Primitive  
form.

According to his theory the shape of every crystal of the same substance is such as can be derived by a particular process from a certain fundamental figure called the PRIMITIVE FORM, the shape and angles of which depend only on the nature of the substance itself. The process consists simply in the replacement of the edges or the solid angles (corners) of the primitive form by single planes or by groups of planes, but always in such a way that the total alteration is similarly related to all parts of the primitive form which are geometrically similar; these planes of replacement he regarded as secondary and more or less accidental. With a view to the development of this theory, Romé de l'Isle proceeded to determine the shape of the primitive form of every kind of known substance, whether natural or artificial; and he was able to do this with a certain degree of precision by means of an instrument for the measurement of angles, invented by Carangeot, to whom he had entrusted the preparation of some of the clay-models intended to illustrate his theory. He was thus led to the discovery that the angles between the faces of a primitive form are always the same for the same kind of substance, and are characteristic of it. For example, he found that while the primitive form of alum, nitre and sugar is in each case an

Specimen.

Invention  
of a  
goniometer.

\* Essai de Cristallographie. Paris, 1772. Cristallographie, ou description des formes propres à tous les corps du règne minéral. Paris, 1783.

octahedron, the angles of the primitive forms are different, for that which in alum is always  $110^\circ$ , is  $120^\circ$  in nitre and  $100^\circ$  in sugar.

Kinds of  
primitive  
form.

21. The different kinds of primitive form met with by Romé de l'Isle in his examination of natural and artificial crystals were only six in number (Fig. 4), namely :—

Models.

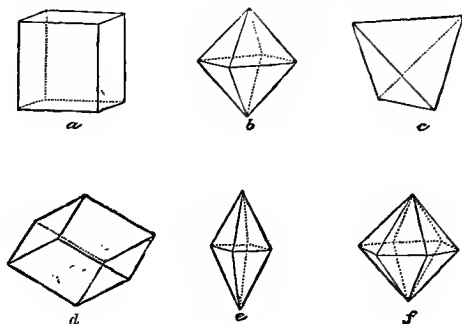


Fig. 4.

- a. The cube,
- b. The regular octahedron,
- c. The regular tetrahedron,
- d. The rhombohedron,
- e. The octahedron with a rhombic base,
- f. The double six-sided pyramid.

In the first three of these figures there can be no variety since they are by definition fixed in their angles, but in the latter three there may be any number of shapes due to difference in angle.

22. To make the theory of Romé de l'Isle more clear it will be necessary to enter a little into detail ; and in the first place we shall trace the varieties of crystalline form which his theory would lead one to expect to meet with in a mineral having the *cube* for primitive form. The illustrative specimens belong to the mineral Fluor.

Modifica-  
tions of the  
cube.

The faces of a cube being six equal squares, they are geometrically similar: all the twelve edges are likewise geometrically similar, for they are of equal length and are formed by faces meeting at the same inclination, namely, a

Model and  
Specimen.



right angle: all the eight solid angles are geometrically similar, for each of them is formed by the meeting of three similar edges all intersecting at the same inclination, a right angle. Any natural alteration of an edge of this primitive form we may expect to be similarly related to the two similar faces meeting in the edge, and any natural alteration of a solid angle to be similarly related to the three similar edges meeting in the solid angle; further, we may expect the same alterations to be repeated on all the similar edges and solid angles of the figure.

1. If an edge of the cube be replaced by a single face, the face must be equally inclined to the two similar faces meeting in the edge; and this alteration must be repeated on all the edges, since they are similar (Fig. 5). Model and Specimen.

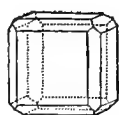


Fig. 5.

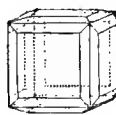


Fig. 6.

2. If an edge be replaced by a face unequally inclined to the two faces meeting in that edge, a second face must also be present to make the total alteration similar with respect to the similar faces; and a similar pair of faces must replace each of the remaining edges (Fig. 6). Model and Specimen.

3. If a solid angle be replaced by a single face, the face must cut off equal lengths from the three similar edges forming that solid angle; and a similar face must replace each of the other solid angles. Models and Specimens.

As these new faces increase and the faces of the original cube

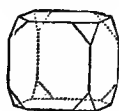


Fig. 7.



Fig. 8.



Fig. 9.

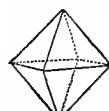


Fig. 10.

diminish in size, there is a gradual transition from the cube to the regular octahedron (as shown in Figs. 7, 8, 9, 10).

*Its application to the cube.*

4. Of the latter figure the faces, edges and solid angles are respectively similar. Hence, just as in the cube, if an edge be replaced by a single face, the face must be equally inclined to the two similar faces meeting in the edge; and the alteration must be repeated on all the remaining edges (Fig. 11). Model.



Fig. 11.

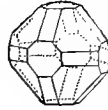


Fig. 12.

5. And again, a solid angle of the last figure may be replaced by a single face cutting off equal lengths from the edges meeting in the solid angle; and the alteration must be repeated on the remaining solid angles (Fig. 12). Model and Specimen.

6. Returning to the cube, if a face replacing a solid angle cut off equal lengths from two of the edges, but a different length from the third edge, meeting in the solid angle, the total alteration will only be similarly related to the three similar edges if two additional faces come into existence; and a similar group of three faces must replace each of the remaining solid angles (Fig. 13). Model.

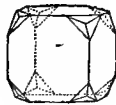


Fig. 13.

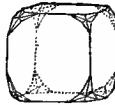


Fig. 14.

7. And, finally, if a face replacing a solid angle of the cube cut off unequal lengths from the three edges which meet in the solid angle, the total alteration will only be similarly related to the three similar edges if five other faces come into existence; and a similar group of six faces must replace each of the remaining solid angles (Fig. 14). Model and Specimen.

23. To make the theory still more clear we shall now apply it to the more difficult case where the primitive form is a *rhombhedron*: the relation between the derived forms will be more evident to the reader if he refer to the exhibited models, in which corresponding edges or faces are indicated by an identity

of colour, rather than to the figures given in the text. The specimens illustrating the varieties of form are selected from the mineral Calcite.

The rhombohedron.

We must first ascertain which are the similar edges and similar solid angles of such a figure.

Like the cube, the rhombohedron (Fig. 15) has six equal faces, each bounded by four equal edges; it differs from the cube in that the angles formed by these four edges instead of being all equal are only equal in pairs, one of which we may denote by  $a$  and the other by  $b$ .

Model and Specimen.

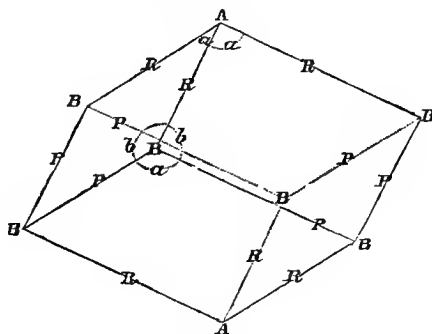


Fig. 15.

Its similar solid angles.

If now the rhombohedron be examined, it will be found that two opposite solid angles are geometrically similar to each other, each being contained by three plane angles  $a$ ; but that these are different from the remaining six, which are in turn similar to each other, each being contained by two plane angles  $b$  and one plane angle  $a$ . Each of the first pair of similar solid angles is denoted in the figure by the letter A, and each of the remaining six by the letter B.

Its similar edges.

We have seen above that all the edges are equal in length; edges are, however, not *geometrically similar* unless they are formed by similar pairs of planes making the *same angle* with each other, or when they join similar pairs of solid angles. Thus the six edges denoted in the figure by the letter R are similar in that each of them joins a solid angle A to a solid angle B; but they are not similar to the six zig-zag edges denoted by the letter P, for these join only the solid angles B.

Or again, we have seen that each of the solid angles  $A$  is formed by three edges  $R$  having the same inclination to each other, namely, the angle  $a$ ; whence it follows that the edges  $R$  are formed by planes having equal inclinations and are geometrically similar to each other. Also, since three edges which meet to form a solid angle  $B$ , are unequally inclined to each other, they cannot be all geometrically similar; the two edges  $P$ , however, make the same angle  $b$  with the edge  $R$ , and are so far similar to each other but not similar to  $R$ ; it is further seen that the two edges  $P$  are contained by planes making the same angle, and that the angle is different from that between the planes which meet in the edge  $R$ .

Hence we conclude, that in a rhombohedron there are, from a geometrical point of view, two similar solid angles  $A$ , and six similar solid angles  $B$ ; six similar edges  $R$ , meeting by threes in the pair of solid angles  $A$ , and six similar edges  $P$ , arranged in zig-zag form and passing by pairs through the six solid angles  $B$ ; but the solid angles  $A$  are not similar to the solid angles  $B$ , nor the edges  $R$  to the edges  $P$ .

We now proceed to indicate some modifications of form which will be consistent with the theory enunciated by Romé de l'Isle.

Modifica-  
tions of the  
rhombo-  
hedron.

1. Each of the similar solid angles  $A$  may be replaced by a single face cutting off equal lengths from the three similar edges  $R$  meeting in the solid angle (Fig. 16). Model and Specimens.



Fig. 16.

2. Each of the similar edges  $R$  of Fig. 17 (which represents a new position of the same rhombohedron) may be replaced by a single face equally inclined to the pair of faces meeting therein; as the new faces increase and the old faces diminish in size, there is a gradual transition to a more obtuse rhombohedron (Figs. 17, 18, 19 and 20). Models and Specimens.

3. Each of the set of six similar solid angles  $B$  of this new rhombohedron (Fig. 21) may be replaced by a single face, cutting off Models and Specimens.

equal lengths from the two similar edges and a different length from the third dissimilar edge meeting therein ; if one of these

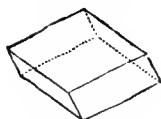


Fig. 17.

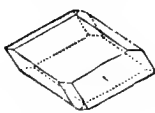


Fig. 18.



Fig. 19.



Fig. 20.

new faces be parallel to the line joining the pair of similar solid angles A, the remaining five faces will also be parallel to it and the six faces will form a regular six-sided prism ; in Fig. 22 the faces of the prism are small, and in Fig. 23, large.



Fig. 21.



Fig. 22.



Fig. 23.



Fig. 24.

4. And again, each end of the last figure may be replaced by a single face cutting the six similar edges of the prism at the same inclination, a right angle (Fig. 24). Model and Specimen.

5. Returning to the original rhombohedron (Fig. 25), each of the six zig-zag edges P may be replaced by a single face equally inclined to the pair of similar faces meeting therein (Fig. 26). Model.

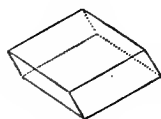


Fig. 25.

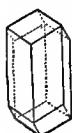


Fig. 26.

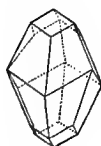


Fig. 27.



Fig. 28.



Fig. 29.

6. If, on the other hand, a face replacing one of these edges P be unequally inclined to the two faces meeting in the edge, a second face must come into existence to make the total alteration similarly related to the similar faces ; and a similar Model and Specimen.

pair of faces must replace each of the remaining edges P (Fig. 27).

7. If the new faces increase until the old ones disappear, the resulting form is that shown in Fig. 28.

8. And finally, each of the set of six similar solid angles of the last figure may be replaced by a single face parallel to the line joining the pair of similar solid angles, thus giving rise to the shape shown in Fig. 29. Model and Specimen.

24. Such is the way in which Romé de l'Isle connected together the various crystalline forms met with in the same kind of mineral. Some idea of the great advance in the knowledge of the forms of crystals which we owe to this mineralogist may be gained from an examination of the clay-models made for him by Lermina and Carangeot to illustrate the 'Treatise of 1783. One of these sets, which were the first ever made to illustrate a theory of crystals, is shown in window-case X.

Difficulties  
of the  
theory,

25. The theory was extremely successful in indicating that the crystalline forms of a mineral belong to one connected series. Its weak point was that the whole series could be derived in this way, not only from the primitive form itself, but from almost any one of the figures of the series, and that thus no hard and fast rule could be given for the determination of the true primitive; Romé de l'Isle himself was guided in his choice of the primitive by largeness of development and frequency of occurrence of particular faces, and by the simplicity of character of the figure formed by them; but in practice such a method presents great difficulties. It was owing to this mode of choice that he was led to adopt both the cube and the regular octahedron as distinct primitive forms, although, as we have seen, they are really terms of one series, and can be derived the one from the other by similar alteration of the similar solid angles.

26. Many of his contemporaries, however, went so far as to doubt not only the accuracy of his choice of the primitive form, but the very existence of the series; and, ten years after the publication of the *Essay on Crystallography*, we find the

Buffon. illustrious Buffon,\* in his Natural History of Minerals, treating of the new science as follows:—

“ It has been claimed that crystallisation in rhombohedra is the specific character of Calcite; neglecting the fact that certain vitreous and metallic substances likewise crystallise in rhombohedra, and further, that although Calcite does seem to take by preference a rhomboidal figure, it takes also forms which are very different. Our crystallographers, in borrowing from the geometers the method by which a rhombohedron may be transformed to an octahedron, a pyramid and even a lens (for there is a lenticular spar), have only substituted ideal combinations for the real facts of Nature. No crystallisation will ever afford a specific character, for the variety is infinite; not only are there forms of crystallisation common to several substances of different nature, but, conversely, there are few substances of like nature which do not offer different forms of crystallisation. It would thus be more than precarious to establish differences or resemblances, real and essential, by means of this variable and almost accidental character.”

The truth  
is not  
obvious.

27. That so distinguished a naturalist as Buffon could decline to recognise the correctness of the new theory is itself a testimony to the difficulty of the step which had just been taken. It was, indeed, not obvious on inspection that all the crystalline forms of a mineral belong to one series; and this is sufficiently evidenced by the discovery having been postponed to the time of Romé de l'Isle. The reasons are not far to seek: in the first place, as Romé de l'Isle himself remarks, mineralogists had not at that time begun to collect specimens conspicuous for the excellence of their crystalline form, having been content with such as well displayed the colour and lustre of a mineral, or the grouping of its crystals: in the second place, as was noticed above in the case of Rock-crystal, the symmetry of the arrangement of the angles may be almost hopelessly disguised by the differences in size of the corresponding faces.

\* *Histoire naturelle des Minéraux.* Paris, 1783–8.

Haüy's  
discovery  
of the  
importance  
of cleavage

28. The abbé Haüy,\* however, soon broke down all opposition to the new science by discovering that a certain figure of the series of crystallisations has a distinct claim, if not an absolute right, to recognition as the true primitive form, and also that a wonderfully simple law controls the positions of the secondary faces.

These important discoveries we now proceed to explain. Specimen.  
A six-sided prism of Calcite had fallen from Haüy's table and had been broken in a way which attracted his attention: the fracture instead of being irregular like that of glass, presented a smooth plane face "with Nature's polish." On trial Haüy found that, with the help of a knife, further slices could be split off, not only parallel to the new face, but also in other directions similarly related to the alternate edges of the prism; and by carrying on the division to a certain point, he reduced (as indeed had been already done by Gahn, the pupil of Bergmann) the six-sided prism to a rhombohedron. Repeating this experiment on other specimens of the same mineral, Haüy found that, whatever the outer form, the crystal could be reduced by cleavage to a kernel which always had exactly the same shape and the same angles; and that, treating this kernel as the primitive form, all the various crystallisations of Calcite could be derived from it by the process of Romé de l'Isle explained above. Extending the area of his experiments, Haüy found that this property was not peculiar to Calcite, but a general one; whence he inferred that the kernel obtained from a mineral by cleavage must be regarded as its true primitive form.

Haüy's  
primitive  
forms,

29. The various kinds of primitive form obtained by him Models. during a long course of investigation were the following:

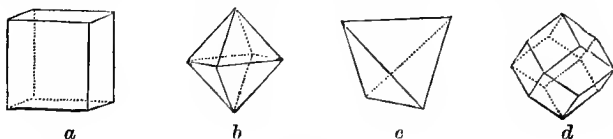


Fig. 30.

1. The cube,
2. The regular octahedron,

\* *Essai d'une théorie sur la structure des cristaux.* Paris, 1784.



- 3. The regular tetrahedron,
- 4. The rhombic dodecahedron (Fig. 30);

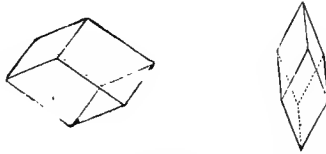


Fig. 31.

- 5. The rhombohedron, obtuse or acute (Fig. 31);

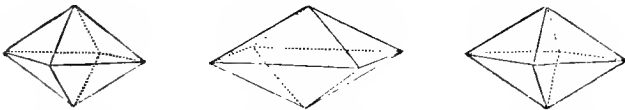


Fig. 32.

- 6. The octahedron, with square, rectangular, or rhombic base (Fig. 32);

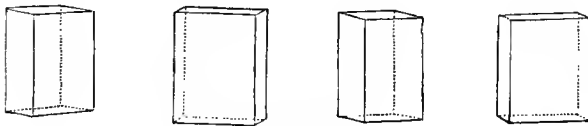


Fig. 33.

- 7. The four-sided prism, with edges at right angles to the base, the base being either a square, a rectangle, a rhomb, or merely a parallelogram (Fig. 33);

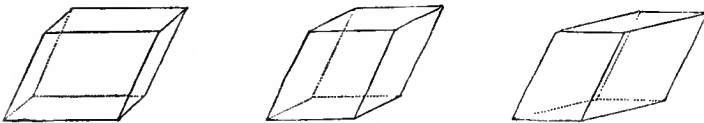


Fig. 34.

- 8. The four-sided prism, with edges inclined obliquely to the base, the base being either a rectangle, a rhomb, or merely a parallelogram (Fig. 34);

9. The regular six-sided prism (Fig. 35);  
 10. The double six-sided pyramid (Fig. 36).



Fig. 35.

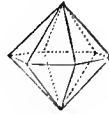


Fig. 36.

30. Haüy further grouped these numerous figures into different kinds in another way :

- (1) Figures bounded by parallelograms (Figs. 30*a*, 30*d*, 31, 33, 34).
- (2) Figures bounded by eight triangles (Figs. 30*b*, 32).
- (3) The regular tetrahedron (Fig. 30*c*).
- (4) The regular six-sided prism (Fig. 35).
- (5) The double six-sided pyramid (Fig. 36).

His theory  
of the  
structure  
of crystals.

31. By his study of cleavage Haüy was led to frame a theory of the *structure* of crystals, and to discover a law which connects the secondary faces with those of the primitive form.

He found that the kernel obtained by the cleavage of any crystal can be itself split up, and apparently without limit, for a plane of cleavage parallel to a face of the kernel is obtained, starting from any point at which the knife is placed.

Not believing in the infinite divisibility of crystals, Haüy was led to imagine that every crystal of the same substance can, theoretically at least, be reduced by cleavage to minute bricks of a definite size and shape, though too small to be separately visible.

32. Conversely—he argued—it must be possible from these minute bricks to build up a crystal having any of the forms presented by the mineral; it is only necessary to discover the mode in which the bricks must be arranged. For simplicity take the case where the little bricks are cubes.

In the first place, the resulting structure is to have the property of cleavage, and at all its parts the faces obtainable by cleavage are to have the same directions. Hence not

only must the cubes be arranged parallel to each other in rows and layers, but they must not be interlocked, as are the bricks of an ordinary wall wherein cleavage is to be specially guarded against.

In the second place, the outer surface of the structure is to consist of a series of plane faces. A cube of any dimensions can be made still larger by adding to each of the faces layers of the proper size: but suppose that, starting from any edge of the cube, every new layer is just one row of bricks less in extent than the previous one; the layers will now be arranged in regular steps ascending from this edge, and all their edges will lie in a plane, just as those of a flight of stairs can all be touched by a carpenter's straight-edge (Figs.

Models.

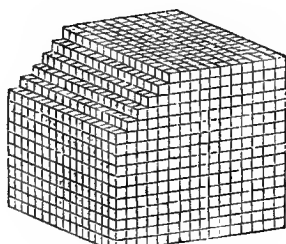


Fig. 37.

37 and 38a). But the little bricks being really too small to be separately visible, the steps will appear to be wholly in this plane, and will thus form a secondary face equally inclined to two faces of the cube, for in each step the height

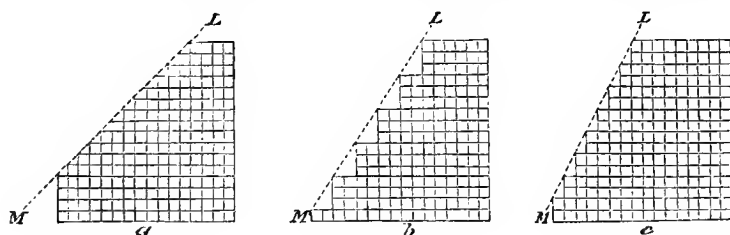


Fig. 38.

is equal to the width. In the same way, a secondary face, having with respect to the faces of the cube an inclina-

tion different from the above, but still determinable either by construction or by calculation, would be produced by the regular omission of two, three or more rows, or by the deposition of layers two, three or more bricks in thickness: in Fig. 38, LM shows the inclinations of the secondary face to those of the cube when each step is (a) one brick wide and one brick high, (b) two bricks wide and three bricks high, and (c) one brick wide and two bricks high.

If the arrangement of steps shown in Fig. 37 start from all the similar edges and be similarly disposed with regard to the

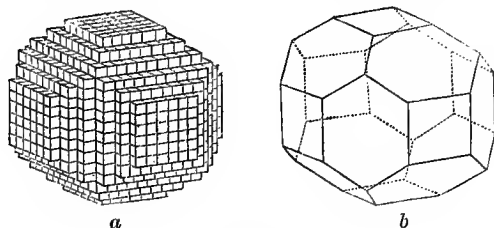


Fig. 39.

similar faces of the primitive form, there will result such a group of steps as is shown in Fig. 39a, and, if the bricks be too small to be separately visible, such a group of faces as is shown in Fig. 39b: the same group can be derived from the cube by the process of Romé de l'Isle (Fig. 5), as indicated in § 22.

Haüy's law  
of whole  
numbers.

**33.** If the theory of Haüy be true, it follows that the secondary faces have not absolutely arbitrary positions, as had been supposed by Romé de l'Isle, but only such as would result from the omission of whole numbers of rows, and from the layers having a thickness measured by some multiple of that of a single brick.

In fact, Haüy proved by measurement of a vast number of crystals that the inclinations of the secondary faces to those of the primitive form are such as would result in this way, and that the number of bricks in the width or height of a step is a very simple one, rarely exceeding six.

**34.** Such, briefly stated, is Haüy's theory of the structure of

crystals. It is so simple, and moreover so completely consistent with the results of measurement, that the existence of series of crystallisations of the same mineral, all derivable according to simple laws from a primitive form characteristic of the mineral, was no longer questioned.

Objections  
to Haüy's  
theory of  
structure.

35. And yet the objections to the theory itself are very serious. It by no means follows that, because a crystal may be reduced by cleavage to certain fragments, the growth has taken place by the grouping together of the same fragments; and, indeed, we know that in slaty rocks the direction of cleavage is quite distinct from that of the planes of deposit. Again, some minerals have no distinct cleavage; others appear to be distinctly cleavable only in one or two directions: and as a solid figure can not be bounded by faces having fewer than three directions, it is difficult to grant that in such minerals there is any cleavage-kernel at all. A more serious objection still is that when the cleavage-form is an octahedron, as in the case of Fluor, it is impossible to arrange the constituent bricks so as to completely fill up space; in fact, that the little octahedra may be parallel to each other and have their faces in directions parallel to the cleavages of the resulting crystal, they have to be arranged with only their angular points in contact, and it is difficult to see that such a skeleton-like structure would not immediately collapse. Further, the two acknowledged facts, namely, the existence of series of crystallisations and the dependence of the positions of the secondary faces upon whole numbers, would still be explained in the same way if, instead of the cleavage-kernel, some other figure of the series were adopted as the primitive form.

Since the time of Haüy, the atomic theory of the constitution of matter has led to a more philosophical treatment of the facts which gave rise to his theory of crystalline structure. In the mathematical investigations made by Bravais, and lately extended by Sohncke, the idea of brick-like units in actual contact with each other has given place to that of atomic groups, the centres of mass of the latter being imagined to be arranged in the same way as the centres of the bricks of the original theory—namely, in straight lines and parallel planes. These investigations have furnished results of great interest to the student.

Invention of axes and of systems of crystallisation by Weiss and Mohs independently.

**36. Weiss,\*** the Professor of Mineralogy at Berlin, was the first to invent a mode of treatment which connected together the facts without requiring the assistance of any theory of structure at all.

In the first place, he arranged the primitive forms of Haüy into four classes, each distinguished by a purely geometrical character.

- I. By joining the centres of the opposite faces of the cube, or the opposite solid angles of the regular octahedron, or the three pairs of similar solid angles of the rhombic dodecahedron, or the middle points of opposite edges of the regular tetrahedron, he obtained in each case three equal lines at right angles to each other.
  - II. Similarly, from the octahedron or the right prism with a square base, he again obtained three lines at right angles, but now only two of them were of equal length.
  - III. From a rhombohedron, or a regular six-sided prism, or a double six-sided pyramid, he obtained three lines in the same plane, all equal in length and equally inclined to each other, and a fourth line differing from the others in length and having a direction perpendicular to their plane.
  - IV. From an octahedron or a four-sided prism not having a square base, he obtained three lines at right angles but all of different lengths.
- 37.** Conversely, starting from these four classes of sets of lines, Weiss deduced all the *primitive* forms of Haüy by constructing planes which passed:—
- i. —through ends of three lines,
  - ii. —through ends of two of the lines and parallel to a third,
- or iii.—through an end of one of the lines and parallel to two of them.

\* De indagando formarum crystallinarum caractere geometrico principali dissertatio. Lipsiæ, 1809. Uebersichtliche Darstellung der verschiedenen natürlichen Abtheilungen der Krystallisations-systeme. (Deusch. d. Berl. Ak. d. Wissensch. 1814–15.)

In other words, the planes either passed through an end of a line or else would not meet that line at all.

**38.** In the second place, he found that by taking points along each of these lines at twice, three times and four times, &c., the original length, and constructing planes in the same way as before, he obtained a set which included all those *secondary* planes of which the actual existence on crystals had been demonstrated by Haüy.

These fundamental lines Weiss called *axes*.

**39.** A little later, but quite independently, **Mohs**,\* the successor of Werner at Freiberg, arrived by a different process of reasoning at the same division into four classes, or, as Mohs now called them, *systems of crystallisation*.

The process was identical with that of Romé de l'Isle (§§ 22 & 23), except that the positions of the derived planes were now limited by the law of whole numbers, in that the lengths cut off by these planes from each one of certain lines of the fundamental figure were in the ratio of whole numbers. The kinds of fundamental figure, each giving rise to a separate system of crystallisation, were as follows :

- 1.—The cube ;
- 2.—The octahedron with a square base ;
- 3.—The rhombohedron ;
- 4.—The octahedron with a rhombic base ;

and the systems of crystallisation derived from these were respectively called the Cubic, Pyramidal, Rhombohedral, and Prismatic ; they correspond exactly with the groups I., II., III., IV. of Weiss.

The notion  
of a  
primitive  
form  
disappears.

**40.** The notion of a primitive form thus disappeared wholly from the crystallography of Weiss, and almost from that of Mohs. The latter does, in truth, appear to take a primitive figure, but he employs it merely to *define* the series, and this

\* The characters of the classes, orders, genera, and species ; or, the characteristics of the Natural History System of Mineralogy. Edinburgh, 1820. Treatise on Mineralogy ; or, the Natural History of the Mineral Kingdom : (translated from the German). Edinburgh, 1825.

might be done by means of any one of its figures: thus, exactly the same series of planes may be derived by his processes from the regular octahedron as from the cube.

The faces, which are predominant, or constantly occur, or are directions of cleavage, were regarded by neither Weiss nor Mohs as the *origin* of the series.

A simple form.

41. Since all similar edges and solid angles of each fundamental figure of Mohs were to be similarly altered, the existence of a single derived plane necessitated, as was the case in the theory of Romé de l'Isle, the simultaneous existence of a number of others having definite positions; such a set of faces was called by Mohs a *simple form* of crystallisation. Thus the regular octahedron, being derivable from the cube by a similar alteration of all the similar solid angles, is a simple form.

A combination.

If the faces of more than one simple form are present on a crystal (Figs. 5-9, 11-14), the resulting compound form is termed a *combination*.

As crystals generally exhibit combinations, and further, (§§ 16 & 27) the faces which are crystallographically similar usually vary considerably both in shape and size, such a series of large crystals as those of Fluor and Calcite shown in the case, presenting combinations, at once systematically developed and not too complex to be readily intelligible to the inexperienced, is one which it is difficult to get together; and indeed, the visitor will probably find that the specimens in the General Collection itself have usually forms which can only be interpreted after a most careful study.

Holohedry and hemihedry.

42. But there are sometimes found crystals presenting the faces of the regular tetrahedron; in other words, alternate faces of the regular octahedron are suppressed. Recognising this, both Romé de l'Isle and Haüy had regarded the regular tetrahedron as a distinct kind of primitive form.

To bring such modes of development within the limits of their systems, Weiss and Mohs found it necessary to imagine that simple forms may not only be complete, like the octahedron, but semi-complete, like the tetrahedron: the former kind was termed holohedral and the latter hemihedral. The half which presents itself is, however, not an arbitrary one, but can in



every instance be geometrically derived in a systematic way from the complete simple form.

Discovery of two new systems of crystallisation.

43. Up to the present mention has been made of only four systems of crystallisation. In 1822 the precise measurement of certain crystals by means of a more accurate instrument, the reflective goniometer, invented in 1809 by Wollaston, led Mohs to assert the existence of two additional systems; for he found that the crystals presented forms which could not be referred to the kind of octahedron previously adopted, in which the lines joining the three pairs of opposite angles are perpendicular to each other, but must be referred to a kind of octahedron in which, in one class of cases, two of these lines, and in the other class of cases, all three lines, are obliquely inclined to each other. Weiss, however, so strongly urged objections to the recognition of the new systems, still regarding those crystalline forms merely as developments of half-forms and quarter-forms from rectangular axes, that their independence can only be considered to have been fully established in 1833 by the discovery of the different actions of these crystals on light. The behaviour of minerals with regard to light is so important a character, that we must here make a short digression.

44. Up to the year 1819 no connection had been traced between the form and the physical properties of a crystal, but in that year Brewster discovered that the shape of the cleavage-form is intimately related to the action of the crystal upon light.

The optical characters of Iceland spar.

Since 1669 it had been known that a cleavage-plate of the clear transparent mineral, called Iceland spar, has the strange property of giving a double image of objects seen through it; and that a beam of light, which, for simplicity, we may regard as entering the plate at right angles to its faces, is broken up into two distinct beams of *equal* brightness whatever the position of the plate. It was further found that though the properties of the two emergent beams are the same they are distinct from those of common light, for, if either of the beams be allowed to enter a second plate of Iceland spar, in general two beams of *unequal* brightness emerge; when one of the

Specimens.

Polarised light.

plates is rotated round the beam this inequality varies in degree, and in four positions one or other of the beams quite disappears. The beam of light thus appears to have acquired "sides," and is said to be *polarised*.

Practically, however, it was difficult to isolate either of the emergent beams obtained in this way, for unless the original beam was very small, or the plate very thick, the two beams overlapped and together produced the effect of common light; hence, for a long time, very little progress was made in the study of the action of minerals on polarised light.

Other  
modes of  
obtaining  
it.

In 1808 Malus accidentally discovered that a beam of common light acquires by its reflection at a particular angle from a plate of glass exactly the same characters as are possessed by each of the beams emergent from a plate of Iceland spar; and in 1813 it was discovered by Seebeck that although a beam of common light on entering a plate of the mineral tourmaline is resolved into two, one of them is completely absorbed if the plate is sufficiently thick, and there emerges an isolated beam of polarised light.

We have stated above that either of the beams, obtained by arranging a plate of Iceland spar in the path of a beam of polarised light, can be extinguished by giving to the plate a particular position; if for the plate of Iceland spar there be substituted a plate of tourmaline of the proper thickness, one of the beams will, in all positions of the plate, be destroyed by the absorption, and the single emergent beam, varying in brightness with the position of the plate, will itself, in two positions of the plate, be absolutely extinguished. Such a plate of tourmaline can thus be conveniently used to ascertain whether a given beam of light is common or polarised: if the light is polarised, then for certain positions of the plate the beam is completely extinguished; if, on the other hand, the light is common, the emergent beam is equally bright in all positions of the plate; if the light is only partially polarised, the brightness of the emergent beam varies, but does not become zero, when the plate is rotated round its normal. For the same purpose a plate of glass inclined to the beam at a particular angle may be used.

Hence a plate of glass or tourmaline can be used either as a

Polariser and analyser. *polariser*—for polarising ordinary light, or as an *analyser*—for ascertaining whether or not the light is already polarised.

Brewster's discovery of a relation between the optical character and the form of a crystal.

45. The discovery made by Malus drew the attention of the scientific world to this subject, and for many years nearly all its energy was concentrated on the investigation of light and the alterations produced in it by minerals. At last, in 1819, Brewster\* was able to announce the following general laws:—

A. All transparent crystals of which the cleavage-form is a cube, a regular octahedron or tetrahedron, or a rhombic dodecahedron, are alike in being entirely without action on polarised light.

B. All transparent crystals of which the cleavage-form is a rhombohedron, a regular six-sided prism or a double six-sided pyramid, an octahedron or a prism with a square base, are such that there is one direction, and only one, in which a beam of polarised light of any colour can travel through the crystal and emerge completely polarised, whatever be the position of the crystal. This direction depends only on the shape of the primitive form; in the prisms it is parallel to their edges, and in the other figures parallel to the line joining the pair of similar solid angles.

C. All crystals of which the cleavage-form is other than the above are such that there are two, and only two, directions in which a beam of polarised light of a given colour can travel without alteration; and these two directions are closely related to the shape of the cleavage-kernel. These directions have been called *optic axes*.

The tourmaline pincette. 46. The simplest way of rendering evident these characters is the following:—Between two plates of tourmaline so disposed that no light can pass through the pair, is placed a slice of the crystal to be examined, and the whole apparatus arranged close to the eye, so that light which has passed in various directions Specimen.

\* On the connection between the Primitive Forms of Crystals and the Number of their Axes of Double Refraction: two memoirs. (Proceedings of the Wernerian Society. Edinburgh, 1821.)

through the slice can be at the same time observed. If the slice is that of a crystal belonging to Class A, its introduction between the two tourmalines produces absolutely no change, and the field of view remains dark. If the crystal belongs to Class B, and the faces of the slice are at right angles to the direction along which polarised light can travel without alteration, there will be seen a series of coloured circular rings intersected by a black cross, and the appearance will be un-

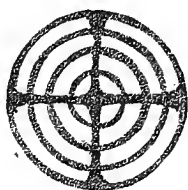


Fig. 40.

changed as the slice is turned round its normal (Fig. 40). If the crystal belongs to Class C, and the faces of the slice are at right angles to a line equally dividing one of the angles between the two directions in which polarised light of a given colour can travel without alteration, the field of view remains dark at two points, around each of which is a set of coloured rings,



Fig. 41.

as shown in Fig. 41. In four positions of the slice the rings are seen to be intersected by a dark cross, but in other positions the dark cross breaks up into two dark bands, termed brushes, each passing through the centre of one of the sets of rings, which, it may be added, appear to move with the crystal during its rotation.

Agreement of the optical and geometrical modes of classifying crystalline forms.

47. This division of crystals into classes according to their optical behaviour is in perfect agreement, as far as it goes, with that which had just before, on geometrical grounds, been suggested in Germany by Weiss and Mohs, and of which Brewster had not at that time heard; the only difference being that optically no distinction could be made between crystals belonging to the systems termed Pyramidal and Rhombohedral by Mohs. Still, Brewster's discovery was quite sufficient to prove that the grouping suggested by Weiss and Mohs is a *natural* one, depending on fundamental differences of structure.

Optical characters of the crystals which had been referred to the two new systems.

48. We have already stated (§ 43) that Mohs afterwards (1822) recognised two additional systems, the crystals belonging to which Weiss and himself had previously regarded as merely developments of half-forms and quarter-forms belonging to the Prismatic system. The independence of these systems was at length confirmed by the difference in the optical characters of the crystals assigned to them.

In those crystals, which both Weiss and Mohs regarded as undoubtedly belonging to the Prismatic system, the two lines which bisect the angles between the optic axes, and a third line at right angles to both of them, were proved to be identical in direction with the three lines which, on geometrical grounds, had been selected for crystallographic axes, and they were also found to be independent both of the colour of the light and the temperature of the crystal. On the other hand, in the fifth system of Mohs two of these lines, and in the sixth system all three, were found to be quite distinct from the rectangular crystallographic axes adopted by Weiss, and to vary in position in the crystal, not only with the colour of the light, but also with the temperature at which the observations were made.

There cannot be more than six systems.

49. The fundamental character of each of these six natural systems is now regarded as one of *symmetry*; in a crystal belonging to the Prismatic system of Mohs, for instance, every feature, whether geometrical or physical, is repeated in directions symmetrically disposed on opposite sides of three rectangular planes. And one of the most remarkable discoveries of the last half-century has been the mathematical demonstration, that

if the law of whole numbers enunciated by Haüy be absolutely true, these six kinds of symmetry, and no others, are possible in crystals.

The  
distinction  
of minerals  
into kinds.

50. We have now indicated the steps by which it has been shown that substances of "the same kind" crystallise in forms which are intimately related to each other, and are capable of reference to one or other of six natural systems.

In case an exception to this general law presents itself, it is necessary, in the first place, to ascertain whether the exception is not an apparent one, for it is possible that the substances may really not belong to the same kind. For instance, in the case of the specimens which had up to his time been called Heavy spar, Haüy discovered that, although the crystals from England and Sicily are very similar in form, those of one locality differ in their fundamental angles from those of the other by amounts not large, but yet beyond the possible errors of measurement. This exception, which long puzzled Haüy, was to his delight removed by the discovery made by Vauquelin, that the crystals really belong to two distinct kinds of mineral (now called Barytes and Celestine respectively), one of them, the English, giving a green, and the other, the Sicilian, a crimson colour to a flame. Specimens.

51. The difficulty as to when two specimens are to be regarded as being of the same kind has so far, for the sake of simplicity, been left out of sight; and we have assumed that, somehow or other, by help of the more obvious properties already mentioned (§ 12), a discrimination into kinds can be made.

Before proceeding further it is necessary to treat with some detail of a very important class of properties, distinct from the rest in that their determination involves the destruction of the part actually tested; if any logical inference as to the concurrence of a group of properties in an individual is to be made, all the other properties must be first determined.

52. The action of fire upon a simple substance or on a mixture of substances, and the action of substances upon each other,

must have been a subject of inquiry in the earliest times (§ 12), one object of desire being the production of a substance more valuable than those destroyed in the process. It was thus discovered that lead can be got by roasting one kind of mineral (galena) with charcoal; a second mineral (tin-stone) yields tin; from a third (magnetite) iron can be obtained; a fourth (cinnabar or vermilion), when rubbed with vinegar in a brass vessel, according to Theophrastus, yields quicksilver. Such properties are clearly of great importance for the distinction of minerals into kinds.

Different kinds of solvents prepared.

53. Several liquids similar to vinegar in having a sour taste and a power of dissolving many substances insoluble in water itself, were discovered by the old alchemists in their search for the philosopher's stone and the elixir of life; these liquids were called *acids*.

Thus, when a certain mineral (iron pyrites) after being roasted or slowly acted upon by the air is treated with water, the resulting liquid yields, on evaporation, a solid termed "green vitriol;" from this, by heating in a retort, a very powerful acid, *oil of vitriol* (fuming sulphuric acid), was obtained.

By heating together a mixture of saltpetre and "blue vitriol," another acid, *aqua fortis* (nitric acid), useful for separating silver from gold, was produced.

In a similar way, from a mixture of nitre, sal-ammoniac, and green vitriol, the alchemists prepared *aqua regia*, a liquid capable of dissolving even gold itself.

And in the fifteenth century another acid, *spirits of salt* (hydrochloric acid), was obtained by heating common salt with oil of vitriol.

The difference of action of each of these liquids on the products belonging to the Mineral Kingdom supplied many tests by which substances very similar in their external characters could be distinguished from each other.

Alkalies.

54. By boiling in water the ashes of plants and evaporating the liquid thus obtained, a substance called *alkali*, having peculiar characters, was prepared; and a similar substance was derived from bones and other animal matters by dry distillation: it was found that the latter could be distinguished from the

former, not only by its pungent smell, but by the action of heat, for it could be completely converted into vapour; hence the two kinds of alkali were termed fixed and volatile, respectively. Later, differences of character between the alkali of land-plants and that of sea-plants were observed, for the colour given to the flame of a spirit-lamp by the former was violet, whilst that given by the latter was yellow; the two kinds of fixed alkali were designated potash and soda.

By being boiled with quicklime, the alkalies acquire characters more pronounced than those they at first possess; the two states of the alkali were distinguished as caustic and mild, respectively.

Opposition  
of the  
alkalies and  
acids.

55. In properties the alkalies were found to be opposite to the acids: they destroy both the sour taste and the solvent power; and whereas the acids turn certain blue vegetable colouring matter to red, the alkalies restore the original colour.

Salts.

56. When the solvent power of an acid was neutralised or destroyed by the action of a metal, an alkali or an earth, another kind of substance called a *salt* was produced.

Alkaline  
earths.

57. About the middle of last century it was remarked that lime, a substance known to the ancients, had similar properties to those of the alkalies; owing to its being almost insoluble in water and to its remaining unaltered when exposed to a high temperature, it had been long regarded as one of the "earths;" it was now termed an *alkaline earth*. Other similar earths, magnesia, baryta and strontia, were soon afterwards distinguished.

58. About this time it was discovered that gases, invisible but yet having very different properties, could be prepared.

Different  
kinds of  
gas,  
recognised.

The gas evolved when limestone was acted upon by an acid was found to be distinct from common air, and was termed *fixed air* (carbonic acid); another gas (oxygen), given off when a certain substance was heated, was found to have very energetic properties; common air was found to be a mixture of the latter with still another gas (nitrogen); a fourth gas (hydrogen), light and inflammable, was obtained by treating iron filings with dilute oil of vitriol: water was shown to be composed of two of these gases (hydrogen and oxygen).

A new  
chemical  
theory.

59. A theory was now proposed which was to account for the peculiarities which had been discovered. The metals, long re-



garded as compounds and as capable of being changed one into another, are, according to the new theory, *elements* incapable of resolution into simpler substances; to this class were also assigned some non-metallic substances, such as sulphur, phosphorus and carbon, and some of the lately discovered gases (hydrogen, oxygen and nitrogen): the number of elements then known was only twenty-three. All other kinds of matter were considered to be *compounds* of the elements with each other. By reason of the facility with which it enters into combination with the other elements, and its influence over the characters of the resulting compounds, oxygen was regarded as the most important of the simple substances. In general its compounds with non-metallic elements are acids, and its compounds with metals are *bases* or substances which have the property of neutralising acids: according to the same theory, a salt is produced by the union of an acid with a base.

The law of combination in definite proportions.

60. The next step was the discovery that every distinct chemical compound always contains exactly the same proportion of the elements of which it is composed; a fact first indicated by the experiments made by Cavendish with neutral salts, for he showed that in these compounds the proportion of base to acid obeys a distinct law; this view, however, was stoutly opposed by Berthollet, and it was not till 1808 that the fact was conclusively established by the researches of Proust.

The atomic theory.

61. About this time Dalton announced his atomic theory. According to this theory there are in Nature different kinds of minute indivisible particles, which Dalton called *atoms*; all atoms of the same kind are the same in figure and in weight; each elementary body consists of only one kind of atom; atoms of different kinds are capable of combining together in simple proportions to form small groups; a definite chemical compound consists of a collection of such atomic combinations, all of exactly the same kind.

The long series of investigations made by Berzelius (and more recently by Stas) to determine with accuracy the relative weights of the different kinds of atom, rendered it so clear that the proportions by weight in which the elements combine to form definite chemical compounds are fixed, that this constancy is now scarcely called in question.

Have  
minerals  
of the  
same kind  
an identical  
chemical  
composi-  
tion?

62. But is a *mineral* a definite chemical compound? To Haüy,\* in 1801, this question presented serious difficulties; and in his Treatise he refers to Felspar as an illustration.

Kirwan had brought together analyses of thirteen different specimens which had all been called Felspar, and to these Haüy adds an analysis made by Vauquelin of a fourteenth specimen. The results varied extremely, for not only were the proportions of the various constituents not constant, but one constituent present in considerable quantity in some of the specimens was entirely absent from the rest. Hence, Haüy was led to criticise the grounds upon which these specimens had been named Felspar; they were as follows:—(1) the specimens were so hard that they gave sparks when struck with steel; (2) they yielded rhomboidal fragments when broken; (3) they were about two and a half times as heavy as water; (4) they were fusible and gave a white bead.

Haüy contended that such properties were not sufficiently definite and precise to serve for the distinction of minerals into kinds (*species*); he therefore recommended that in the distribution of minerals into kinds attention should be paid to the crystalline form, and that specimens should not be regarded as belonging to the same kind of mineral unless their crystals presented the same primitive form. Haüy ventured to assert that when this limitation was introduced all minerals of the same kind would be found to have essentially the same chemical composition, for he could not believe that the little “bricks” could have exactly the same form without being of identical chemical constitution; except where the primitive form is a cube, regular octahedron or tetrahedron, and has thus an absolutely definite shape.

63. Yet Haüy perceived that even where the primitive form is the same there is still much variation in the chemical composition of minerals; and this difficulty he sought to explain in the following ingenious but artificial way. At Fontainebleau are found crystals of Calcite, which have as much as from 50 to 60 per cent. by weight of sand grains disseminated through them, and

\* *Traité de Minéralogie.* Paris, 1801.

yet have the same shape of cleavage-kernel as the pure mineral ; from the fact that this large proportion of mingled foreign matter has failed to influence the angles of the crystals built up from the little bricks of Calcite, Haüy argued that the variations of chemical composition of minerals, which otherwise appear to be of the same kind, are due to the interposition of foreign matter between those constituent particles to which the form of the crystal is really due.

64. The presence of this foreign matter would, according to Haüy, at the same time account for the variations of colour, and for the slight differences of hardness, fusibility and other characters, met with in specimens regarded as belonging to the same kind of mineral. According to this theory, Dolomite, Chalybite and Bitterspar are all varieties of Calcite, the large differences of composition being due to the interposition of carbonates of magnesia or iron between the particles of carbonate of lime, of which the extraordinary crystallising power was supposed to be demonstrated by the Fontainebleau crystals.

Specimens.

Di-  
morphism  
and tri-  
morphism.

65. Haüy thus acknowledged that, in the Mineral Kingdom, crystals having the same primitive form and a general similarity of character may have a very different chemical composition. On the other hand, he found that, in at least one case, crystals yielding a different primitive form have the same percentage chemical composition ; for while one kind of carbonate of lime (calcite) can, as we have seen, be reduced by cleavage to a rhombohedron, a second kind (aragonite), when cleaved, yields an octahedron ; this character has been termed *dimorphism*.\* To those who thence argued that his theory of the association of a definite primitive form with a definite chemical composition must be founded on wrong premises, Haüy replied that at any rate he could not regard two specimens as belonging to the same kind of mineral merely because they had one single property in common, namely, identity of chemical composition ; that the difference of primitive form was, in the case of calcite and aragonite, as also in that of diamond and graphite, associated with differences of hardness, density, and all the other properties, save chemical composition ; and that there was

Specimens.

\* *Di-*, doubly, and *morphe*, form.

no exception to the more general law that a definite primitive form is allied with a definite set of properties.

To remove this exception to the generality of Haüy's theory, countless specimens of aragonite were analysed with the view of discovering some constituent other than carbonate of lime, and it was vainly hoped by some, though not by Haüy himself, that the presence of carbonate of strontium, small quantities of which had been found in some isolated specimens, might be held to account for the difference—an explanation which would require the traces of carbonate of strontium to have such a tremendous power of crystallisation as to completely overcome even that of the carbonate of lime.

In 1822-3 Mitscherlich announced another exception, and showed that while crystals of sulphur deposited from solution have one kind of primitive form, those obtained by allowing melted sulphur to quickly cool have a different one.

By the conversion of aragonite into calcite, and again by the production of both from the same solution, it was eventually made clear that the difference of form, to whatever due, can not be rightly attributed to slight difference in the chemical composition.

Later still (1845), it was shown that titanitic acid is *trimorphous*, appearing in Nature with three distinct primitive forms, each connected with a definite, but different, set of properties.

Iso-  
morphism.

66. To Mitscherlich\* belongs the credit of establishing the existence, not only of artificial crystals having the same chemical composition and different primitive forms (dimorphism), but also of others having the same primitive form and essentially different chemical compositions, a character termed *isomorphism*.† This discovery followed from the examination of a series of phosphates and arsenates of the alkalis, artificial salts of which the purity could be secured. From his investigations Mitscherlich inferred that the chemical elements may be distributed into sets, the members of each of which are so far similar to each other that, in a chemical compound, one

\* Ueber das Verhältniss der Krystallform zu den chemischen Proportionen. Ueber die Körper welche in zwei verschiedenen Formen crystallisiren. (Abhandl. d. Berl. Ak. d. Wissensch, 1822-3.)

† *Isos*, equal, and *morphe*, form.

atom can replace another atom of the same set without appreciably affecting the primitive form of the crystal. Potassium and sodium belong to one of these sets; phosphorus, arsenic and antimony to another. He also inferred that the crystalline form of a chemical compound depends, not only on the percentage composition, but also on the configuration of the atomic groups.

67. The discovery of isomorphism in *artificial salts* removed the great difficulty presented by the fact that, in the Mineral Kingdom, crystals may be different in chemical composition, and yet so similar in form and general characters that they can scarcely be regarded as belonging to different kinds of mineral; for it indicated that although there is not in these crystals that absolute identity of matter which Haüy had been led to expect, still there is an identity of grouping of atoms and a law controlling the replacement of the members of the groups.

Systems of  
classifica-  
tion.

68. Having glanced at the more important properties, by help of which Minerals are distributed into kinds or species, we must next briefly consider how the kinds are to be classified, and thus how we are to ascertain readily whether or not a new specimen, of which the characters have been determined, is similar to some one of the many already described. The great discoveries made in crystallography and chemistry during the latter part of the last century render it unnecessary to discuss the classifications employed in earlier times.

Berzelius.

69. Berzelius\* (1815) was the first to frame a system of classification depending only on chemical composition. The study of electricity had given rise to a theory that the act of chemical combination is an electrical phenomenon; and that every chemical compound consists of two parts, the one electropositive (the metal), the other electronegative (the acid). In his system, Berzelius brought together into one family all chemical compounds having the same electropositive part (the metal), and arranged the families among themselves according to the *degree* of the electropositivity of the metal: each family was distributed into orders arranged according to the degree of electronegativity of the acid part of the compound.

\* Försök till ett rent kemiskt Mineralsystem. Stockholm, 1815.

The arbitrary nature of this system was made manifest by the discovery of isomorphism by Mitscherlich, according to which elements extremely different in electrochemical character can replace each other without appreciably affecting the characters of the compound. Berzelius thereupon acknowledged the completeness of his failure and reconstructed a chemical system (1824), depending now on the electronegative part (the acid): but to this, though more satisfactory in its results, the same objection may be urged, namely that the properties of a mineral have no manifest connection with the electrochemical character of its constituents.

Mohs. 70. About the same time (1820), Mohs\* framed a "Natural History system of classification," wherefrom the chemical composition of a mineral was completely excluded as not being a "Natural History" property, since it could only be determined by destroying the part of the mineral experimented upon. As this system of classification was adopted, more especially in Germany, for many years, and has had great influence on the progress of mineralogical science, a brief statement of its leading features will not be out of place.

In framing the system, account was taken, not of a *single* character, but of *all* the more important of the external (or Natural History) characters, the most prominent in the definition of *species* being crystalline form (including cleavage), hardness and specific gravity.

The first of these has a definite geometrical significance, and the last has a definite numerical value: to give a similar precision to the character of hardness, Mohs constructed an arbitrary scale by means of ten minerals, of which experience had proved the suitability for the purpose; the minerals, in the order of increasing hardness, were:—

- |                     |                  |
|---------------------|------------------|
| 1. Talc.            | 6. Adularia.     |
| 2. Rock-salt.       | 7. Rock-crystal. |
| 3. Calcite.         | 8. Topaz.        |
| 4. Fluor.           | 9. Corundum.     |
| 5. Asparagus-stone. | 10. Diamond.     |

\* The characters of the classes, orders, genera, and species; or, the characteristics of the Natural History System of Mineralogy. Edinburgh, 1820.

For the sake of brevity, the degree of hardness was expressed numerically; a specimen, for instance, which was estimated to be scratched as easily by Fluor as Calcite by the specimen itself, was said to have a hardness 3·5.

According to the system of Mohs, the number of classes of the Simple Minerals is three, of which the characters are as follows:—

**Class I.** Specific gravity under 3·8: no bituminous odour: if solid, a taste.

**Class II.** Specific gravity above 1·8: tasteless.

**Class III.** Specific gravity under 1·8: a bituminous odour: if solid, tasteless.

As few minerals have so low a specific gravity as 1·8 or have a taste, the second class includes nearly the whole of the kingdom, the first consisting, almost solely, of the minerals which are soluble in water, and the last, of the organic products resin and coal.

In **Class II.** are recognised thirteen orders, designated by the following names:—

- |               |              |              |
|---------------|--------------|--------------|
| 1. HALOIDE.   | 5. MICA.     | 9. METAL.    |
| 2. BARYTE.    | 6. SPAR.     | 10. PYRITES. |
| 3. KERATE.    | 7. GEM.      | 11. GLANCE.  |
| 4. MALACHITE. | 8. ORE.      | 12. BLENDE.  |
|               | 13. SULPHUR. |              |

Each of the orders, again, is distinguished by a *combination* of characters: thus, the characters of the order BARYTE are

Lustre: non-metallic.

Streak: uncoloured or orange-yellow.

Hardness: 2·5 to 5·0.

Specific gravity: 3·3 to 7·3.

Further, in this order, the characters are inter-related as follows:—

1. If the most distinct cleavage has only a single direction, the hardness does not lie between 4 and 5.

2. If the lustre is adamantine or imperfect-metallic, the specific-gravity is not less than 5.

3. If the streak is orange-yellow, the specific gravity is at least 6.

4. If the hardness is 5, the specific gravity is under 4·5.

5. If the hardness is 5 and the specific gravity is under 4, the cleavage is diprismatic.

The orders are, in turn, distributed into genera, the number of the latter in the order BARYTE being six, termed respectively :—

1. Parachrose-baryte.
2. Zinc-baryte.
3. Scheelium-baryte.
4. Hal-baryte.
5. Lead-baryte.
6. Antimony-baryte.

The characters of the genus Hal-baryte, for example, are :—

System of crystallisation : orthorhombic.

Hardness : 3·0—3·5.

Specific gravity : 3·6—4·7.

Finally, the genera are subdivided into species: the genus Hal-baryte, for instance, contains four species, designated by Mohs as :—

1. *Peritomous hal-baryte*,
2. *Diprismatic hal-baryte*,
3. *Prismatic hal-baryte*,
4. *Prismatoidal hal-baryte* ;

they are the species known as *Strontianite*, *Witherite*, *Barytes*, and *Celestine*, respectively.

The above is perhaps sufficient both to render evident the difficulty of assigning a relative importance to the various external characters of minerals, and to illustrate the complicated and artificial character of the groups of properties defining the orders recognised in the system of Mohs: at the same time it serves to give an idea of the scientific nomenclature which Mohs sought to introduce for the mineral species.

71. The system which was adopted by Professor Maskelyne for the classification of the British Museum Collection is virtually one published by Gustav Rose,\* in 1852, as an improvement on the purely chemical system, and has been briefly described as a chemical system modified by the principle of isomorphism: it is therefore a mixed system, depend-

Gustav  
Rose.

\* Das Krystallo-chemische Mineralsystem. Leipzig, 1882.



ing on two properties, chemical composition and crystalline form.

In this system minerals are arranged in four principal divisions, of which the first includes the native elements, and the remaining three, the compounds.

The chemical elements most useful in the classification of the compounds met with in the Mineral Kingdom are:—

- (1) The Arsenic group:—arsenic, antimony and bismuth.
- (2) The Sulphur group:—sulphur, selenium and tellurium.
- (3) The Chlorine group:—chlorine, bromine, iodine and fluorine.
- (4) Oxygen.

The second division comprises those minerals in which metals are combined with elements of the Arsenic and Sulphur groups: the third division, those in which metals are combined with the elements of the Chlorine group; and the fourth, the compounds of Oxygen.

The divisions are subdivided into sections, and the sections into classes, the latter embracing the minerals which fall under the same chemical denomination; as, for instance, the salts of the same acid or of a group of acids chemically and crystallographically equivalent to each other.

Each class is further separated into distinct chemical series, the minerals included in any series being such as are designated by the same equivalent typical formula.

Finally, the chemical series are distributed into distinct crystallographic series, arranged according to the crystalline systems to which they belong; these are followed by the amorphous substances, which present either no crystalline forms at all, or only such as cannot be determined.

The accompanying table will serve to give a clearer idea of this system: further detail will be given later in describing the General Collection:—

*The System of Classification  
adopted in the Mineral Gallery.*

SIMPLE MINERALS.	Div. I. Native elements.	Sec. (1). METALLIC.
		Sec. (2). NON-METALLIC.
	Div. II. { The compounds of metals with elements of the arsenic and sul- phur groups.	Sec. (1). ARSENIDES, &c.
		Sec. (2). SULPHIDES, &c.
		Sec. (3). ARSENOSULPHIDES, &c.
		Sec. (4). SULPHUR-SALTS.
Div. III. { The compounds of metals with elements of the chlorine group.	Sec. (1). SIMPLE CHLORIDES, &c.	
	Sec. (2). COMPOUND CHLORIDES, &c.	
Div. IV. { The compounds of oxygen.	Sec. (1). OXIDES.	
	OXYGEN : Class SALTS. : a. Carbonates. : b. Silicates, &c. : c. Molybdates and Tungstates. : d. Chromates and Sulphates. : e. Borates. : f. Nitrates. : g. Phosphates, Arsenates and : Vanadates.	
Supplement.	ORGANIC PRODUCTS.	

## THE CHARACTERS OF MINERALS.



In window-cases II. III. and IV. is arranged a series of specimens illustrating at once the characters of minerals and the terms used in their description: with the view of reminding the student of their existence, characters are specified even when they require experiment for their determination, and are thus not evident from mere inspection of the minerals as they lie in the cases. The names of the illustrative minerals are given in *italics*.

The specimens in window-case II. relate almost entirely to the *Forms* presented by minerals.

### The Forms of Crystals.

Window-  
case II.

THE SIX KINDS OF SYMMETRICAL DISTRIBUTION OF THE FACES :—

The Cubic (or Tesseral) system : *fluor*.

The Tetragonal (or Pyramidal) system : *apophyllite*.

The Rhombohedral (or Hexagonal) system : *calcite, emerald*.

The Orthorhombic (or Prismatic) system : *topaz*.

The Oblique (or Monoclinic) system : *orthoclase*.

The Anorthic (or Triclinic) system : *axinite*.

DIMORPHISM :—*pyrites* and *marcasite*.

TRIMORPHISM :—*rutile, anatase* and *brookite*.

ISOMORPHISM :—*chalybite* and *dolomite*.

PSEUDOMORPHISM :— $\left\{ \begin{array}{l} \text{quartz, calcite, and quartz with the form} \\ \text{of calcite.} \\ \text{galena, pyromorphite, and galena with the} \\ \text{form of pyromorphite.} \end{array} \right.$

FORMS DEPENDING MERELY ON THE RELATIVE SIZES OF THE  
FACES :—

Prismatic (long) : <i>epidote</i> . Prismatic (short) : <i>pyrosmalite</i> . Stout : <i>apophyllite</i> . Slender : <i>scolecite</i> .		Acicular : <i>cerussite</i> . Capillary : <i>millerite</i> . Tabular (thick) : <i>barytes</i> . Tabular (thin) : <i>specular iron</i> .
---	--	--

**The Surface of Crystals :—**

Smooth :	<i>fluor.</i>
Drusy :	<i>quartz.</i>
Rough :	<i>calcite.</i>
Striated :	<i>blende, magnetite.</i>
Curved :	<i>calcite, dolomite.</i>

**The Regular Growths of Crystals (twins) :—**

*Calcite, cassiterite, fluor, gypsum.*

**Groups of Crystals :—**

Parallel :	<i>quartz.</i>
Radiating (or divergent) :	<i>mesolite.</i>
Matted (reticulated or interlaced) :	<i>chalcotrichite.</i>
Confused :	<i>scapolite, beryl.</i>

**Indeterminate forms (due to aggregation) :—**

Globular :	<i>blende, prehnite, calcite, marcasite.</i>
Branched (arborescent or dendritic) :	<i>silver, copper, pyrolusite.</i>
Dentiform :	<i>copper.</i>
Mossy :	<i>copper.</i>
Leafy :	<i>silver, gold.</i>
Wiry (or filiform) :	<i>silver.</i>
Capillary :	<i>millerite.</i>
Coralloidal :	<i>aragonite.</i>
Mammillary :	<i>arsenic, psilomelane.</i>
Warty :	<i>menilite.</i>
Nodular :	<i>blende, malachite.</i>
Botryoidal :	<i>hydrodolomite.</i>
Reniform :	<i>menilite.</i>
Amygdaloidal :	<i>aragonite, agate.</i>
Geode :	<i>quartz.</i>
Stalactitic :	<i>calcite, chalcedony, pyrites, psilomelane.</i>
Amorphous :	<i>websterite.</i>

In window-case III. are collected together specimens illustrative of those characters of minerals which relate to Light. Window-case III.

**The Scale of Colours** (suggested by Werner in 1774):—

**METALLIC COLOURS.**

Copper-red :	<i>copper.</i>
Light-brass-yellow :	<i>pyrites.</i>
Dark-brass-yellow :	<i>copper-pyrites.</i>
Gold-yellow :	<i>gold.</i>
Silver-white :	<i>silver.</i>
Silver-white, passing into grey :	<i>mispickel.</i>
Silver-white, passing into red :	<i>cobalt-glance.</i>
Tin-white :	<i>antimony.</i>
Whitish lead-grey :	<i>stibnite.</i>
Pure lead-grey :	<i>galena.</i>
Blackish lead-grey :	<i>nagyagite.</i>
Steel-grey :	<i>platinum.</i>
Iron-black :	<i>franklinite.</i>

**NON-METALLIC COLOURS.**

**WHITE.**

Snow-white :	<i>aragonite.</i>
Reddish-white :	<i>margarite.</i>
Yellowish-white :	<i>rock-milk.</i>
Greyish-white :	<i>marble.</i>
Greenish-white :	<i>tremolite.</i>
Milk-white :	<i>opal.</i>

**GREY.**

Bluish-grey :	<i>fluor (massive).</i>
Pearl-grey :	<i>perlite.</i>
Smoke-grey :	<i>flint.</i>
Greenish-grey :	<i>hornstone.</i>
Yellowish-grey :	<i>pearlspar.</i>
Ash-grey :	<i>zoisite.</i>

*Scale of colours.*Window-  
case III.**BLACK.**

Greyish-black :	<i>lydian-stone.</i>
Velvet-black :	<i>tourmaline.</i>
Greenish-black :	<i>augite.</i>
Brownish-black :	<i>lievrite.</i>
Bluish-black :	<i>cobalt ochre.</i>

**BLUE.**

Blackish-blue :	<i>chessylite.</i>
Azure-blue :	<i>lapis lazuli.</i>
Violet-blue :	<i>fluor.</i>
Lavender-blue :	<i>teratolite.</i>
Plum-blue :	<i>fluor.</i>
Prussian-blue :	<i>salt.</i>
Smalt-blue :	<i>chalcedony.</i>
Indigo-blue :	<i>vivianite,</i>
Duck-blue :	<i>anhydrite.</i>
Sky-blue :	<i>liroconite.</i>

**GREEN.**

Verdigris-green :	<i>noumeaite.</i>
Celandine-green :	<i>jasper.</i>
Mountain-green :	<i>beryl.</i>
Leek-green :	<i>prase.</i>
Emerald-green :	<i>emerald.</i>
Apple-green :	<i>chrysoprase.</i>
Grass-green :	<i>cuprouranite.</i>
Pistachio-green :	<i>epidote.</i>
Asparagus-green :	<i>asparagus stone.</i>
Blackish-green :	<i>olivenite.</i>
Olive-green :	<i>pyromorphite.</i>
Oil-green :	<i>beryl.</i>
Siskin-green :	<i>calcouranite.</i>

**YELLOW.**

Sulphur-yellow :	<i>sulphur.</i>
Straw-yellow :	<i>carpholite.</i>
Wax-yellow :	<i>mimetesite.</i>
Honey-yellow :	<i>amber.</i>
Lemon-yellow :	<i>orpiment.</i>

## Scale of colours.

65

### YELLOW—continued.

Window-  
case III.

Ochre-yellow :	<i>ochre.</i>
Wine-yellow :	<i>fluor.</i>
Cream-yellow :	<i>halloysite.</i>
Orange-yellow :	<i>wulfenite.</i>

### RED.

Aurora-red :	<i>realgar.</i>
Hyacinth-red :	<i>essonite.</i>
Brick-red :	<i>polyhalite.</i>
Scarlet-red :	<i>cinnabar (earthy).</i>
Blood-red :	<i>pyrope.</i>
Flesh-red :	<i>heulandite.</i>
Carmine-red :	<i>chalcotrichite.</i>
Cochineal-red :	<i>cinnabar (crystallised).</i>
Rose-red :	<i>rose-quartz.</i>
Crimson-red :	<i>ruby.</i>
Peachblossom-red :	<i>lepidolite.</i>
Columbine-red :	<i>almandine.</i>
Cherry-red :	<i>kermesite.</i>
Brownish-red :	<i>jasper.</i>

### BROWN.

Reddish-brown :	<i>tile ore.</i>
Clove-brown :	<i>axinite (massive).</i>
Hair-brown :	<i>barytes (stalactitic).</i>
Chestnut-brown :	<i>jasper (Egyptian).</i>
Yellowish-brown :	<i>przibramite.</i>
Wood-brown :	<i>asbestos (mountain wood).</i>
Liver-brown :	<i>menilite.</i>
Blackish-brown :	<i>limonite.</i>

**A suite of colours of a single mineral :—***fluor.*

**Play of colours :—***precious opal.*

**Change of colours :—***labradorite.*

**Tarnish :—***tetrahedrite.*

**Iridescence :—***quartz.*

**Opalescence :—***moonstone.*

**Asterism :—***star-stone.*

**Pleochroism :—***dichroite.*

**Fluorescence** :—*amber.*

**Phosphorescence** :—*fluor.*

Window-  
case III.

**Refraction and Polarisation** :—

Single refraction : *salt.*

Double refraction (and plane polarisation) : *calcite.*

Circular polarisation : *rock-crystal.*

**The Degrees of Transparency** :—

Transparent : *rock crystal.*

Semi-transparent : *calcite.*

Translucent : *milky quartz (massive).*

Semi- or sub-translucent : *hornstone.*

Opaque : *eisenkiesel.*

**Lustre** :—

THE KINDS OF LUSTRE—

Perfect metallic : *pyrites.*

Imperfect (or sub-) metallic : *pitchblende.*

Common adamantine : *blende (transparent).*

Metallic adamantine : *blende (black),*

Resinous : *colophonite.*

Vitreous : *celestine.*

Waxy : *wax-opal.*

Common pearly : *heulandite.*

Metallic pearly : *bronzite.*

Silky : *crocidolite.*

THE DEGREES OF INTENSITY OF LUSTRE—

Splendent : *blende.*

Shining : *calcite.*

Glistening : *magnetite.*

Glimmering : *galena,*

Dull : *kaolinite.*

**Streak** :—

Shining : *argentite.*

Of the same colour as the mineral : *calcite, malachite.*

Of a different colour from the mineral : *crocoisite, hæmatite, limonite, copper-pyrites.*



The specimens in window-case IV. relate to the remaining characters of minerals. Window-case IV.

**Cleavage:—**

TRUE CLEAVAGE—*Salt, galena, fluor, blende, apophyllite, calcite, corundum, mica, stibnite, topaz, barytes, selenite, hornblende, microcline.*

FACES OF UNION—*sahlite.*

**Fracture:—**

Conchoidal: *calcite, flint, barytes.*

Sub-conchoidal: *quartz.*

Uneven: *semiopal.*

Even: *limestone.*

Splintery: *jade.*

Hackly: *copper.*

**Structure:—**

CRYSTALLINE— *marble, coccolite.*

**LAMINAR—**

Flat: *slate spar.*

Flat and divergent: *pyrophyllite.*

Curved: *specular iron.*

**FIBROUS TO COLUMNAR—**

Straight: *asbestos.*

Curved: *bosjesmanite.*

Straight and parallel: *gypsum, tremolite, satin-spar.*

Radiating: *wavellite, natrolite.*

Divergent: *celestine.*

Matted: *pilolite.*

Columnar: *anthraconite.*

**GRANULAR—**

Coarsely: *magnetite, colophonite,*

Finely: *magnetite.*

**COMPLICATED—**

Layers: *agate, onyx, calcite, pisolite.*

Curved layers made up of grains: *allemontite.*

Curved layers made up of fibres: *hæmatite.*

**Sectility:**—*chlorargyrite*.**Malleability:**—*argentite*.**Ductility:**—*copper*.**Frangibility:**—Brittle: *sulphur*.Tough: *fibrolite*.Soft: *molybdenite*.Friable: *sassoline*.**Flexibility:**—*talc*.**Elasticity:**—*mica*.**Hardness:**—

The scale of hardness.

- |                       |                      |
|-----------------------|----------------------|
| 1. <i>Talc</i> .      | 6. <i>Adularia</i> . |
| 2. <i>Rock-salt</i> . | 7. <i>Quartz</i> .   |
| 3. <i>Calcite</i> .   | 8. <i>Topaz</i> .    |
| 4. <i>Fluor</i> .     | 9. <i>Corundum</i> . |
| 5. <i>Apatite</i> .   | 10. <i>Diamond</i> . |

Differences of hardness on different faces of the same crystal: *calcite*.Differences of hardness along different directions in the same face: *salt*.**Specific gravity** (relative to that of water):—Between 1 and 2: *mellite*.„ 2 and 3: *quartz*.„ 3 and 4: *topaz*.„ 4 and 5: *zircon*.„ 5 and 6: *bourmonite*.„ 6 and 7: *scheelite*.„ 7 and 8: *wolfram*.„ 8 and 9: *copper*.„ 9 and 10: *bismuth*.„ 10 and 19: *silver, amalgam, gold, platinum*.**Magnetic characters:**—

PARAMAGNETIC—

Strong, with polarity: *magnetite*.Strong, without polarity: *magnetite*.Weak: *ilmenite*.

DIAMAGNETIC—

*bismuth*.

**Electrical characters :—**Due to pressure : *calcite*.Due to friction : *amber, topaz*.Due to changing temperature (pyro-electricity) : *tourmaline, boracite*.Due to difference of temperature at the points of contact with another substance (thermo-electricity) : *bismuth, pyrites*.Window-  
case IV.**CONDUCTIVITY—**Good : *silver*.Bad : *diamond*.**Thermal characters :—**DILATATION : *calcite*.ACTION UPON RADIANT HEAT : *rock-salt*.CONDUCTIVITY : *quartz*.**Touch :—**Unctuous : *steatite*.Meagre : *tripoli*.Harsh : *trachyte*.Adhesive to the tongue : *hydrophane*.**Smell :—**Bituminous : *elaterite*.Sulphurous (on friction) : *pyrites*.Garlic-like (on friction) : *mispickel*.Empyreumatic (on friction) : *anthraconite*.Clayey (on breathing) : *kaolinite*.**Taste :—**Astringent : *chalcantbite*.Sweetish astringent : *alum*.Saline : *salt*.Alkaline : *natron*.Cooling : *nitratine*.Bitter : *epsomite*.

## RECENT ADDITIONS.

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For a short time previous to their dispersion through the General Collection, recent additions are arranged for inspection in the fifth window-case on the left-hand side of the Gallery. Window-case V.

In the remaining fifteen window-cases of the Gallery are arranged series intended rather for those who are making a minute study of minerals, and are provided with text-books, than for the readers of a Guide.

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## THE CRYSTALS AND CRYSTAL MODELS.

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In window-cases VI.-IX. is a series of specimens illustrative of the manifold character of crystalline form. In addition to specimens of crystals met with in Nature, there is displayed a fine suite of so-called artificial crystals prepared by Carl von Hauer, and presented to the Trustees in 1862 by Her Majesty the Queen. The term *artificial* is in such case intended to imply, not that the specimens have been cut, but merely that the conditions under which the crystals have been deposited from solution have been artificially induced. Window-cases VI.-XIII.

Those at the end of window-case IX. are instructive as examples of the character of isomorphism; in each instance a crystal of one kind of substance has been transferred from the solution in which it has been formed to another which would deposit crystals of the same shape; instead of being destroyed, as is generally the case when a soluble crystal is immersed in a different kind of solution, the specimen has continued to grow. In some of the examples the change has been repeated several times, as is particularly evident where the solutions have been of different colours.

Window-cases X.-XIII. contain a series of crystal-models invaluable to the student.

## THE PSEUDOMORPHS.

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In the remaining window-cases, XIV.-XX., is shown a most extensive and instructive series of pseudomorphs—that is to say, minerals presenting a form characteristic, not of their own, but of some other substance. Pseudomorphs illustrate the decomposing influences to which many minerals have been subjected, and they throw valuable light on the order of succession in which, and the conditions under which, particular minerals have been formed and deposited; and, in furnishing us with sure proofs of conversions which we can never hope to effect in the laboratory, they afford us a knowledge of facts which can be arrived at in no other way.

Pseudomorphs are of three kinds, due respectively to Encrustation, Alteration, and Replacement of the original mineral.

By encrustation. In window-case XIV. are shown the Encrustation pseudomorphs, or epimorphs, as they are sometimes called; in these the pseudomorphous mineral obtains its form through simple encrustation of crystals of another mineral. As a good example may be mentioned the first specimen in the case, where thin crusts of quartz have the form of crystals of calcite. Window-case XIV.

By alteration. In window-cases XV., XVI. and XVII., are the Alteration pseudomorphs, arranged in groups according to the kind of alteration which has taken place:

- (i.) Loss of a constituent; or,
- (ii.) Gain of a constituent, both in window-case XV.; or,
- (iii.) Exchange of constituents, in window-cases XVI. and XVII.

An example of the first group is the first specimen in window-case XV., in which cuprite, a compound of copper and oxygen, has lost its oxygen and been altered to copper. Window-case XV.

As an example of the second group we may indicate the first specimen beneath the middle pane of the same case, in which cuprite has been altered to malachite through the addition of carbonic acid and water.

An example of the third group is furnished by the first specimen in window-case XVI., in which pyromorphite, a compound of phosphate and chloride of lead, has been altered to galena, a sulphide of lead, through the replacement of the arsenic acid and the chlorine by sulphur. Window-cases XVI. and XVII.

In each of these specimens the form of the original mineral has been retained.

By replacement. In window-cases XVIII. and XIX. are the Replacement pseudomorphs, in which there has been a complete substitution of one substance for another. A good example of this kind of pseudomorph is the first specimen in window-case XVIII., where hæmatite (oxide of iron) has the form of calcite (carbonate of lime). Window-cases XVIII. and XIX.

Para-morphs. The first specimens in window-case XX. are of the kind known as paramorphs, in which there has been a re-arrangement of the molecules and a corresponding alteration in the mineral characters, the percentage chemical composition and the form, however, remaining unchanged. Window-case XX.

Pseudo-morphs after organic remains. These are followed by some minerals which have the forms of various organic remains; they afford a very convincing proof of the possibility of a change of substance without alteration of form.

The Pinite group. As a supplement to the collection of pseudomorphs, there is also arranged in this case, a series of minerals known as the Pinite group. Most of them result from the alteration of dichroite, and their composition, depending as it does on the extent of the alteration, is too indefinite to allow of the products being classed with the simple minerals.



## THE MINERAL SPECIES AND THEIR VARIETIES.

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### DIVISION I.

#### THE NATIVE ELEMENTS.

OF the 65 elementary bodies into which matter has been resolved by the chemist, the few which have been found in Nature in the uncombined state are shown in cases 1 and 2: they are arranged in two sections, Metallic and Non-Metallic elements. This division of the elements, though convenient, is quite arbitrary, for no sharp line of division can be drawn between the two sections.

Sectioni.—  
Metals.

With the native metals are placed the native alloys, or compounds and mixtures of metals which belong to the same chemical group.

**COPPER.** This native metal, with silver and gold, has been known from the earliest times. The first locality known to the ancients is said to have been the Island of Cyprus, and to the name of that island the word copper is itself related. The toughness of the metal, and the hardness of its alloys made it highly valued by the ancients as a material for tools and weapons.

Case 1ab.

During the present century the finest crystals and the largest masses have been furnished by the mines of Russia and of the neighbourhood of Lake Superior: in one of the mines of the latter locality there was found, in 1859, a mass estimated to weigh upwards of 400 tons; its length was 45 feet, and its greatest width and thickness 22 feet and 8 feet, respectively; 40 men were employed for 12 months in extracting it.

Though the crystals of native copper are rarely symmetrical in appearance attention may be directed to the branch of cubes from the Lake Superior mining region, (case 1b) and to the groups and tree-like growths of crystals from the mines of the Urals (case 1a). As instances of the variety of form of the native metal we may also mention :—the large irregular water-<sup>Case 1a.</sup> worn mass brought from a copper mine near the Coppermine River by Mr. Hearne and presented to the Trustees in 1818; the thin plate from Barr Head, Renfrew; the dendritic<sup>Case 1b.</sup> and the mossy growths from Cornwall; and the long branches from the Lake Superior district, of which the largest (presented by Prof. Ruskin) is to be seen in the lower part of the case.

SILVER is found native in a large variety of forms and in<sup>Cases 1c-2a.</sup> many localities.

Magnificent specimens have been obtained from the mines of Kongsberg in Norway: one of them, now in the Royal Collection at Copenhagen, weighs upwards of 5 cwt.

Amongst the specimens here shown we may remark :—dendritic growths from Potosi, Freiberg and Peru; bundles of coarse fibres from Chañarcillo; groups of fine curved fibres from Wheal Vincent, Cornwall; and native foil from Sultepec mine, Mexico; all in case 1c: a nugget, weighing thirty-seven ounces, from Peru; a mass of crystals and a long branch from Kongsberg; all in case 2a.

Native silver is seen intermingled with native copper in the<sup>Case 1c.</sup> specimens from Lake Superior: when fused together and allowed to cool under ordinary circumstances, an alloy of the two metals is formed.

GOLD, one of the most widely occurring of minerals, is almost<sup>Case 2b-e.</sup> always found either in and about veins of quartz-rock or in alluvial deposits.

The native gold from our own islands, in case 2b, and the various nuggets from Australia and California brought together in case 2d, are well worthy of attention; the Latrobe nugget is especially remarkable as showing crystalline structure. A fine suite of specimens, collected in Brazil by Captain Lyon,<sup>Case 2d.</sup> R.N., is exhibited.

Specimens illustrating the varieties of crystalline form will be found in case 2c. Other forms of occurrence are the leaf-



gold and the dendritic growths, of which many specimens are shown in case 2c and 2e.

A large mass of quartz from Costa Rica, estimated to contain above 50 oz. of finely divided gold, will be seen in the lower part of case 2.

The rare association of visible gold with galena is illustrated by specimens from Beresovsk and the Argentine Confederation (case 2b); while specimens from Ädelfors (case 2b) and the Solferino reef (case 2d), show the exceptional occurrence of gold in carbonate of lime.

Native gold always contains more or less silver, and when the proportion reaches about 20 per cent. is called *Electrum*; the crystalline forms of electrum are generally much more sharply defined than are those of the purer gold. Beautiful specimens of the pale gold from Transylvania are shown in case 2e; the percentage of silver in some of the specimens from that country reaches 38 per cent. Case 2e.

A variety of gold called *Porpezite* is rich in palladium; a small specimen is shown in case 2c.

Models of some of the most interesting gold nuggets are shown in the upper and lower parts of the case.

IRON, LEAD and TIN are of very restricted occurrence in the native state; almost all the iron thus met with is believed to have fallen from the sky, and many specimens of it are shown in the Collection of Meteorites in the Pavilion: the iron found at Ovifak by Professor Nordenskiöld is, however, now regarded by most mineralogists as having had a terrestrial origin. The iron of commerce is obtained from its "ores," among which we may especially mention magnetite, hæmatite, limonite, chalybite and clay iron-stone: the lead of commerce is in great part extracted from galena, a compound of lead with sulphur; and the tin of commerce from cassiterite or tin-stone, a compound of tin with oxygen. Case 2ef.

PLATINUM is another valuable native metal, generally found in small grains but occasionally in rather large nuggets; one in the case weighs upwards of forty ounces. The metal was first met with in South America. After its discovery in the Urals an attempt was made to introduce a platinum coinage in Russia, but without success, owing to the irregularity in the Case 2f.

amount produced, though platinum to the value of £400,000 is said to have been coined between 1826 and 1844. Platinum is one of the heaviest metals known: it weighs in the native state 17 or 18 times, and when purified  $21\frac{1}{2}$  times, as much as an equal volume of water. It is almost infusible, and is attacked by few substances, properties which render it of great value as a material for chemical apparatus.

IRIDOSMINE is a rare mineral containing the metals iridium Case 2f. and osmium, and is generally found associated with platinum. It is used for the tips of the nibs of gold pens, on account of its hardness and the difficulty with which it is acted upon by acids.

MERCURY, or Quicksilver, though found native, chiefly as Case 2f. small globules, is generally extracted from the mineral cinnabar, in which it exists in combination with sulphur. Though metallic in its general characters it is remarkable as being liquid at ordinary temperatures; it is the densest liquid known, being  $13\frac{1}{2}$  times as heavy as its own volume of water. It is much used for thermometers and barometers, the silvering of mirrors, the extraction of gold and silver from their ores, and the preparation of the artificial compound with sulphur, the *vermilion* of commerce.

NATIVE AMALGAM. The "mixtures" of mercury with other Case 2f. metals are called amalgams. That known as native amalgam is found almost wholly in the Landsberg mine in the canton of Ober-Moschel, Rhenish Bavaria; it contains from 25 to 35 per cent. of silver. Remarkably good crystals are shown in the case.

Arsenic, antimony and bismuth form a group of metals of which the crystals present the symmetry of the Rhombohedral system and have almost identical angles: with these is placed the much rarer element tellurium, of which the Case 2h. crystals present similar characters; its chemical properties, however, associate it rather with the element sulphur, which immediately follows it in the arrangement of the Collection.

ARSENIC is rarely found in distinct crystals: it is often granular in structure and mammillary in shape: though initially Case 2g. tin-white it is soon altered to a dark grey by exposure. Simple metallic arsenic is not itself of much importance in the arts, but the alloy with lead has been found useful as a material for the

manufacture of shot. The metallic arsenic required for commerce is for the most part obtained by roasting mispickel, a compound of arsenic with sulphur and iron.

ANTIMONY, though found native, is chiefly obtained for commerce from the much more plentiful mineral stibnite, in which the metal is combined with sulphur. It is very valuable for the manufacture of type-metal, an alloy of antimony with lead and tin: this alloy, like water, presents the exceptional property of increasing in volume when passing from the liquid to the solid state; it thus, whilst solidifying, keeps in constant contact with the mould and takes a sharp impression. Britannia metal and pewter are alloys of antimony with tin. Case 2g.

ALLEMONTITE is remarkable as being a compound of the two similar elements antimony and arsenic: of the latter it contains 65 per cent. Case 2g.

BISMUTH is chiefly found native: a very fine mass from Bolivia, rich in gold, is shown in the lower part of the case: specimens also are shown from Cornwall and Saxony. This metal has the peculiar property of forming alloys with lead and tin which melt at a very low temperature, some of them far below the boiling point of water: these alloys are much used in the process of stereotyping. The metal is also employed in the manufacture of some kinds of solder. Case 2g.

Section ii.  
—  
Non-  
metallic  
elements.

In the second section of native elements is placed sulphur; and also diamond and graphite, the two native modifications of the element carbon.

SULPHUR. The specimens of this mineral are from their colour, transparency, size, and sharpness of crystalline form, among the most magnificent of natural products: very fine groups of crystals from Sicily and Spain will be found in the upper and lower parts of the case. Sulphur generally occurs in the neighbourhood of volcanoes, active or extinct, and is often associated with gypsum. Most of the sulphur required for commerce is brought in the native state from Sicily: in France, Germany and Sweden it is also artificially prepared by

Cases  
2h, 1ef.

distillation from pyrites. It is employed in medicine (the common brimstone); and also in the manufacture of gunpowder and of oil of vitriol.

DIAMOND and GRAPHITE, though chemically only different Case 1f-h, states of the element carbon, are almost completely opposite in their general characters. The diamond is the hardest of all known minerals; graphite is one of the softest: diamond is generally found in very symmetrical transparent crystals, generally colourless or faintly yellow, but sometimes with blue, grey, or other tints; graphite, on the other hand, rarely, if ever, occurs in well defined crystals; it is opaque, black in colour, and has a metallic lustre quite different from that of the diamond: diamond, too, is a very bad conductor of electricity, graphite an excellent one.

The diamond, from its rarity and hardness, has long been regarded as the most precious of the decorative stones; its superiority of lustre and brilliancy have been rendered even more conspicuous by the discovery, made not many centuries ago, that this, the hardest of stones, can be cut and polished by means of its own powder.

The diamond becomes strongly electric on being rubbed: when it is heated or exposed to a strong light it becomes luminous, and retains the character for several hours.

The collection of mounted crystals is extremely remarkable Case 1g, as representing a great variety of crystalline form. A very symmetrical South African crystal, weighing 130 carats, the Case 1f, property of Professor Ruskin, is exhibited; the triangular markings on the octahedral faces, so characteristic of the diamond, are in this specimen extremely distinct.

Models of some of the most famous diamonds are shown in the case.

Those specimens which are useless to the jeweller, owing to imperfect crystallisation (when the specimens are known as Case 1f, *Boart*) or to flaws, have considerable value for the lapidary, by whom they are reduced to powder and employed in cutting and polishing the precious stones.

There is found in Brazil a black uncrystallised variety of carbon, called *Carbonado*, which has the hardness of the dia- Case 1f, mond, and is in much request for the drilling of hard rocks:

to this purpose the diamond itself is not suited, for, notwithstanding its great hardness, it easily splits in certain directions related as usual to the crystalline form; of this property the diamond-splitter avails himself for removing the parts containing flaws, and for shaping the specimens before the polishing is begun. Very few diamonds are now found in India, where the once famous mines of Golconda are situated: almost all those of commerce are brought from Brazil and South Africa.

It is not known how the diamond has been produced in Nature, and it is even doubtful whether it has ever been found in the place where it was originally formed: specimens of the pebbles amongst which the diamond has been met with in Brazil and India and of the rocks in which it occurs in South Africa, are shown in the case.

GRAPHITE, also known as *Plumbago* or *Blacklead*, has many <sup>Case 1h.</sup> uses. In its purest form it is the material of blacklead pencils: excellent graphite for this purpose was long supplied by the mines of Borrowdale in Cumberland, now worked out. The less pure forms are employed for the polishing of stoves and for reducing the friction of machinery; large quantities from Ceylon are mixed with clay and made into crucibles at the Battersea works.

The specimens from New Cumnock show a columnar structure, probably caused by the heat from a neighbouring trap-dyke. A curious fibrous structure is also conspicuous in some of the specimens from Battugol.

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## DIVISION II.

### THE COMPOUNDS OF METALS WITH ELEMENTS OF THE ARSENIC AND SULPHUR GROUPS.

In the first of the four sections of this division are placed those minerals in which arsenic, antimony or bismuth is combined with a metal of another group: the second section includes those compounds of metals with sulphur, selenium or tellurium, in which the latter are regarded as playing a

part analogous to that of oxygen in the oxides: in the third section are arranged the minerals wherein certain arsenides of section i. are combined with the sulphides of section ii., or which may otherwise be looked upon as the result of a replacement of half the arsenic of the minerals of section i. by its equivalent of sulphur: the fourth and last section comprises those minerals in the chemical constitution of which sulphur is regarded as playing a part analogous to that of oxygen in the oxygen-salts, a class of compounds hence termed sulphur-salts.

Section i.—  
the  
arsenide  
group.      **DYSCRASITE** is a compound of antimony and silver, and Case 3a,  
contains from 77 to 85 per cent. of the precious metal.

**NICKELINE** is a compound of nickel and arsenic, and an Case 3a,  
important source of the nickel of commerce; the alloy of this  
metal with copper and zinc is the well-known German silver.  
The metal is at present chiefly used for electroplating with  
silver.

**SMALTINE**, a compound of cobalt and arsenic, is the mineral Case 3b,  
from which blue enamel colours, particularly smalt, are  
prepared.

**CHLOANTHITE** is the corresponding compound of nickel and Case 3c,  
arsenic, and is another source of the metal nickel.

**SKUTTERUDITE** is a compound of cobalt and arsenic, crystal- Case 3c,  
lising in forms analogous to those of pyrites.

Section ii.  
—the  
sulphide  
group.  
The mono-  
sulphide  
series.      **ARGENTITE** is an important ore of silver, 100 parts contain- Cases 3d,4a,  
ing 87 of that metal combined with 13 of sulphur: before  
exposure to the light it has a bright metallic lustre, but soon  
after exposure becomes coated with a dull dark powder: the  
mineral is remarkable as being perfectly sectile. Good  
specimens from Freiberg, Chili, and also Cornwall, will be  
found in the cases.

**BLENDE** is an important ore of zinc: 100 parts of the Case 4b-d,  
mineral contain 67 of zinc and 33 of sulphur.

A particularly fine suite of specimens is shown in the case.  
Specimens of blende containing the new and rare element Case 4d,  
gallium, presented by Mr. W. G. Lettsom, are exhibited.

Occurring in many parts of the world and having been  
produced under many different conditions, the crystals of

blende present a considerable variety in their forms, all of which can be referred to that section of the Cubic system of which the tetrahedron is a prominent type, and they thus afford material for the study of that kind of hemihedry. It has been found that while all alternate faces of the octahedron are similar to each other, the adjacent ones differ in lustre, striation and smoothness, and also in the angles which the associated faces make with them. The crystals are rarely simple growths, being generally twinned upon the faces of the octahedron.

GALENA is by far the most important ore of lead: 100 parts Case 4e-h. of the mineral contain 87 of lead and 13 of sulphur. The crystals from Rossie and from Neudorf are very sharply defined. A large crystallised specimen from the Great Laxey mine is shown in a corner of the Pavilion.

ALABANDITE is the corresponding compound of manganese and sulphur. Case 4h.

PENTLANDITE is a compound of iron, nickel and sulphur, Case 4h, and is commercially important as a source of nickel.

COPPER-GLANCE, or Redruthite, is an important ore of copper: 100 parts contain 80 of copper and 20 of sulphur. Case 3e-g. The suite of specimens from Cornwall is unique for excellence and variety of crystalline form. The mineral is altered by exposure to light.

CINNABAR is the ore from which mercury (or quicksilver) is obtained by heating: 100 parts contain 87 of mercury and 13 of sulphur: the same compound artificially prepared is the *vermilion* of commerce. Cases 3h, 5a. Almost the only localities known are those of Almaden in Spain, Idria in Austria, Moschel in Rhenish Bavaria, and New Almaden in California.

WURTZITE is interesting as crystallising in the Rhombohedral system, though it has the same chemical composition as blende. Case 5a.

GREENOCKITE is a very rare mineral found in association with prehnite and stilbite; it was first met with in cutting the Bishopston tunnel on the Glasgow and Greenock railway; it is a compound of sulphur and cadmium. The corresponding artificial compound is the pigment *cadmium yellow*. Case 5ab.

MILLERITE is another source of the metal nickel: the wool-like form from St. Louis is worthy of notice. Case 5b. Considerable

*Disulphide series.*

quantities of this mineral have been obtained from the Gap mine, Lancaster county, Pennsylvania.

CROOKESITE, is remarkable as containing 17 per cent. of thallium : it is a selenide of copper and thallium with about 5 per cent. of silver.

NAGYÁGITE is a telluride of gold and lead, in which some of the tellurium is replaced by sulphur.

The  
disulphide  
series.

HAUERITE, beginning the series of disulphides, is the disulphide of manganese; its crystals present the same kind of hemi-symmetry as those of pyrites. Case 5d.

PYRITES, or Iron-pyrites, contains 47 of iron and 53 of sulphur in 100 parts. Though one of the most common of minerals, the difficulty of getting rid entirely of the sulphur prevents it from being employed for the manufacture of iron: it is, however, extensively used in the preparation of the green vitriol and oil of vitriol of commerce. Cases 5d, 6ab.

Just as blende is useful for the study of that hemi-symmetry of the Cubic system in which only the symmetrical character of the cube-planes is in abeyance, so pyrites with its manifold forms is of the greatest value for the study of that kind of hemi-symmetry in which only the symmetry relative to the dodecahedron-planes is wanting. The specimens from Elba and Traversella are especially worthy of remark.

G. Rose with very doubtful success has sought to prove that the complementary semiforms of this mineral are associated with opposite thermo-electric characters.

MARCASITE, having the same chemical composition and the same commercial uses as the last named mineral, has from its lighter colour been called "White iron pyrites;" but the differences in the crystalline form and other characters make it necessary to regard the two kinds as different species. The crystals of marcasite are far from being so distinctly formed as those of pyrites. They generally group themselves into peculiar shapes, thus giving rise to the fanciful terms, Spear pyrites, Cockscomb pyrites, &c. Case 6b.

MOLYBDENITE is the disulphide of molybdenum, and is the chief source of the molybdenum salts; it is very similar in Case 6c.



appearance to graphite, from which it was only distinguished in 1778.

REALGAR is the disulphide of arsenic, and occurs in crystals Case 6c. of a beautiful aurora-red colour; as on exposure to light the mineral is soon altered to a yellow powder, the specimens are kept in the drawers.

The sesqui-  
sulphide  
series.

LAURITE is a sulphide of the rare element ruthenium, of which Case 6d. metal part is replaced by osmium: it has only been found in Borneo, where it occurs associated with platinum.

SYLVANITE is a telluride of silver and gold. Case 6d.

STIBNITE, or Antimonite, a compound of sulphur and antimony, Case 6e. is much used for the preparation of the metal and its salts, of which a large number have been employed in medicine: in the East the powdered mineral is used for painting the eyebrows. The specimens from Felsobanya and Japan are especially worthy of notice; a magnificent specimen from the latter locality is shown in the Pavilion.

BISMUTHITE is the corresponding sulphide of bismuth. Case 6f.

ORPIMENT is the corresponding compound of sulphur and Case 6g. arsenic: the artificial compound was one of the ingredients of the pigment *king's yellow*, now superseded by the harmless *chrome-yellow*.

Section iii. COBALT-GLANCE, or Cobaltine, like smaltine, is highly valued Case 6g. as an ore of cobalt: and is a compound of that metal with the arseno-sulphide group. arsenic and sulphur. Its crystals are similar to those of pyrites in the development of their faces.

NICKEL-GLANCE is the corresponding compound of nickel; and Case 6g.

ULLMANNITE is a similar compound of nickel in which the greater part of the arsenic is replaced by antimony.

MISPICKEL, a compound of arsenic, sulphur and iron, is the Case 6h. chief source of the arsenical compounds of commerce.

DANAITE is a variety of mispickel containing cobalt. Case 6h.

GLAUCODOTE is a similar compound, in which still more of the Case 6h. iron has given place to cobalt.

Section iv.  
—the  
sulphur-  
salts.

The first and somewhat ambiguous group of sulphur-salts is regarded as containing  $\text{Fe}_2\text{S}_3$  or  $\text{FeS}_2$  as part of the "acid" component.

**PYRRHOTINE**, or Magnetic pyrites, is a compound of iron and sulphur. The specimen from Morro Velho, presented in 1883 by Mr. F. Tendron, is unusually fine; good specimens are also shown from the Miggiandone mine. Case 5e.

**ERUBESCITE** is a valuable ore of copper, and contains that metal in combination with sulphur and iron: the copper varies from 60 to 70 per cent. Case 5e.

**COPPER-PYRITES**, or Chalcopyrite, is the most important of copper ores, and contains the same elements as erubescite but in different proportions, the copper amounting to only 35 per cent. It is also used for the preparation of the "blue copper" (copper sulphate) of commerce. For general excellence the series of specimens in the case is unequalled. Case 5f-h.

The crystals of this mineral belong to the Tetragonal system, and are of great interest to the student as being almost the only representatives in that system of a hemi-symmetry corresponding to that of blende in the Cubic. The twin-growths, too, are especially important in their characters: remarkably good examples of a kind of growth almost, if not quite, peculiar to this mineral are shown from Cornwall and Freiberg (case 5g).

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The next and largest group of sulphur-salts is that consisting of sulph-arsenites, sulpho-bismuthites and sulph-antimonites.

**STEPHANITE** is a sulph-antimonite of silver, and is an important silver ore. Case 5h.

**TETRAHEDRITE**, or Grey copper ore, a most valuable ore of copper, belongs to this class; it is a sulph-antimonite of that metal, part of which is frequently more or less replaced by silver, iron and zinc. The specimens from Cornwall, which are coated with copper-pyrites and tarnished, are very beautiful. Case 7ab.

**TENNANTITE** is the corresponding compound in which the antimony is replaced by arsenic. Case 7b.

Both the latter minerals crystallise in the Cubic system, and present a hemi-symmetry similar to that of blende.

**BOURNONITE** is a sulph-antimonite of copper and lead; the specimens from Herodsfoot mine are unique for size and splendid lustre. Case 7d.

**PYRARGYRITE** is a sulph-antimonite, and **PROUSTITE** a sulph-arsenite of silver; before they are blackened by ex- Case 8a-c.

posure to light they have a beautiful blood-red colour, which becomes deeper in tint as the antimony preponderates over the arsenic, the two species being isomorphous and blending the one into the other. The pyrargyrites from Mexico and the Harz are particularly fine, while the mass of resplendent crystals of proustite from Chili, presented by Mr. H. Ludlam, is unique; unfortunately, for the above mentioned reason, it requires to be protected from the light. Pyrargyrite and proustite are important ores of silver.

JRDANITE is a sulph-arsenite of lead: very good crystals from the Binnenthal are shown in the case. Case 8d.

XANTHOCONITE is a sulph-arsenate of silver; of this rare mineral a specimen from Chili, associated with proustite, is probably unique for its excellence. Case 8e.

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### DIVISION III.

#### THE COMPOUNDS OF METALS WITH ELEMENTS OF THE CHLORINE GROUP.

Section i.—  
Simple  
chlorides,  
&c.

SYLVINE, of which fine specimens are exhibited, is a compound of the metal potassium with the element chlorine: it is very similar in its characters to common salt. Case 8f.

SALT, or Common salt, is a compound of the metal sodium with chlorine. It occurs chiefly in beds, often of great thickness and extent, and is present in solution in salt-lakes and brine-springs. The Great Salt Lake of Utah, which has an area of 2000 square miles, contains 20 per cent. by weight of common salt in solution. The Dead Sea contains 20–26 per cent. of solid matter, and one-third of this is common salt. The waters of the ocean contain 4 per cent. of solid matter in solution, and about three-fourths of this is common salt. The most famous mines are those of Wielicza, in Austria, which have been worked for the last 600 years; the beds of salt are there so thick that they have been excavated into houses, chapels and other ornamental forms, and the mines, when illuminated, are regarded as one of the sights of Europe. The salt mines of Cheshire are also well-known. Case 8f.

A beautiful crystallised specimen from Wielicza, presented in 1862 by the Austrian Government, is in the case.

Some specimens are of a deep blue colour, which disappears Case 8g. when the salt is dissolved in water.

SAL-AMMONIAC is the corresponding compound of ammonium Case 8g. and chlorine, and is found as a sublimation product near to volcanoes and ignited coal seams. That required for commerce is artificially prepared: it is valuable in medicine, and is also used by tinmen in soldering.

CHLORARGYRITE, Cerargyrite or Hornsilver, contains 75 per Case 8h. cent. of silver and 25 per cent. of chlorine, and is a valuable ore of the metal. Chlorargyrite is remarkable for its malleability and sectility; it is blackened by exposure to the light.

EMBOHITE contains 70 per cent. of silver, the remainder con- Case 8h. sisting of variable proportions of chlorine and bromine: it is the principal silver ore furnished by the mines of Chañarcillo, in Chili.

FLUOR is a compound of calcium with fluorine: an extensive Cases suite of specimens in the cases illustrates the varieties of colour 7e-h, 9ab. and crystalline form presented by this beautiful mineral. Large quantities of the violet-blue variety (Blue John) have, until lately, been found in veins in the limestone of Derbyshire, and more especially in the large caves in the Castleton district. The Derbyshire fluor is wrought into various ornamental articles: it takes a good polish, but on account of its easy cleavage is difficult to work. With the exception of the pink Case 7g. variety found in Switzerland, all the finest specimens of this mineral are of English origin. Fluor is also employed as a flux in the reduction of various ores; and the hydrofluoric acid prepared from it is used for etching glass.

CALOMEL is a chloride of mercury; the artificial salt is much Case 9b. used in medicine.

FLUELLITE is a very rare mineral of which minute crystals Case 9c. were found some years ago in Cornwall. It is a hydrated fluoride of aluminium.

CRYOLITE is a double fluoride of aluminium and sodium; it Case 9c. occurs forming a large bed or vein at Arksutfiord in Greenland. It is used for the preparation of commercial carbonate of soda, and also of metallic aluminium.

## DIVISION IV.

### THE COMPOUNDS OF OXYGEN.

As the chemically energetic element, oxygen, forms a fifth part of the atmosphere by which our Earth is surrounded, and is by far the most important constituent of the water which is nearly everywhere present, the minerals having oxygen for one of their constituent elements are, as might be expected, very numerous. In fact, all the minerals which by their aggregation form the rocks of the crust of the Earth fall under this chemical division.

Just as the compounds with sulphur are divided into sulphides and sulphur-salts, the compounds with oxygen are divided into oxides and oxygen-salts; the distinction, though difficult to define with logical precision, yet serves one important object of a system of classification in that it brings together compounds which, in their general characters, bear a close resemblance to each other.

Oxy-  
chlorides,  
&c.

At the beginning of the first section are placed the minerals in which oxides or hydrates are combined with the chemical compounds which fall under the last division.

**MATLOCKITE** is an oxychloride of lead: very fine crystals of this mineral will be found in the case. Case 9c.

**MENDIPITE** is another oxychloride of lead, containing twice the proportion of lead oxide present in matlockite. Case 9c.

**ATACAMITE** is a hydrated oxychloride of copper: fine crystals from South Australia are exhibited. Case 9d.

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The oxides are so arranged that those containing the greater proportion of oxygen follow after those that contain less: commencing with the basic oxides, we thus pass through certain comparatively neutral oxides, among which we must look for those which possess the most equivocal claim to a place in the section, and we then come to the higher oxides which act the part of acids in combining with bases.

The first series is that of the monoxides.

**Monoxides.** **CUPRITE**, or Ruby copper, is an important ore of copper, of which metal it contains 89 per cent. It is found in beautiful transparent ruby-coloured crystals, which are rapidly blackened by exposure to light. Cuprite gives a very intense red colour to glass. Case 10a-c.

*Chalcotrichite* is a variety of cuprite in which the crystals are bright red and capillary, and are not so subject to alteration by light. Unequalled specimens both of cuprite and of chalcotrichite are in the collection. Case 10c.

*Tile ore* is an earthy variety of the same mineral. Case 10b.

PERICLASE, the corresponding oxide of magnesium, has been found only in the agglomerates of Monte Somma. Case 10c.

ZINCITE, or Spartalite, is a very valuable ore of zinc found only in New Jersey: the red colour is probably due to a small proportion of an oxide of manganese. The corresponding artificial compound is used as a white paint. Case 10c.

MELACONITE, or Black copper, is another compound of oxygen and copper, and contains 80 per cent. of the metal. In some mines it has been found in quantities sufficient to make it a very valuable ore. Case 10c.

BRUCITE is a hydrate of magnesium: the specimens from Wood's mine are unusually fine. Case 10d.

.....

Epitrit-  
oxides.

The next series in the section of oxides is formed by minerals of which the chemical type is similar to that of magnetite; but while, regarded as oxides, they are represented by the same typical formula, they have also some claim to be regarded as oxygen-salts.

The first of this class is the Spinel group, which includes spinel, magnetite, chromite and franklinite, all of them crystallising in the Cubic system.

SPINEL in its transparent varieties is one of the precious stones: the deep-red is the *Spinel Ruby* (less dense and less hard than the true Ruby), the rose-tinted is the *Balas Ruby*, and the yellow or orange-red is the *Rubicelle* of the jewellers: sometimes, too, it has a dark blue colour. On account of their hardness the less valuable specimens are used for the jewellery of watches. Specially worthy of notice are a large polished octahedron, and a small growth in which the twinning is repeated in a peculiar way. Case 10ef.

Spinel may also be regarded as an aluminate of magnesia: varieties, chiefly opaque, are produced by the replacement of the magnesia and of the alumina by other oxides; among these are *automolite*, *dysluite*, *kreittonite*, and *pleonaste*.

MAGNETITE, or Magnetic iron ore, is the richest and most valuable of the ores of iron, of which metal it contains 72 per Case 10fg.

cent. Magnetite is one of the most widely occurring of minerals : it is remarkable for its magnetic properties, and is found presenting polar characters : it is the natural loadstone. The crystals from Nordmark and the Binnenthal are very bright and sharply defined.

CHROMITE is the corresponding oxide of chromium and iron : Case 10gh. it is the chief source of the salts of chromium, which are extensively used as dyes and pigments.

FRANKLINITE is another member of this group ; it is first Case 10h. worked for zinc, and then the residue is treated as an iron ore.

PITCHBLENDÉ consists almost entirely of oxygen and Case 10h. uranium. From this mineral are obtained the uranium compounds used in porcelain painting, and yielding yellow and black colours.

HAUSMANNITE has the same type of formula as the members of Case 10h the Spinel group, and is an oxide of manganese ; it crystallises, however, in the Tetragonal system.

CHRYSOBERYL belongs to this series of oxides ; it may also Case 9e. be regarded as an aluminate of beryllium. In its transparent varieties it is one of the precious stones : the beautiful greenish-yellow variety, almost equal in lustre and hardness to the sapphire, is the *Oriental Chrysolite* of the jewellers ; another variety, with a peculiar play of light, is the true *Cat's-eye* ; while a third, green by sunlight but red by candle- or lamp-light, is the stone known as *Alexandrite*. Very fine twin-growths, and cut specimens of these varieties, are shown in the case.

Sesqui-  
oxides.

The next series is that of the sesquioxides.

BRAUNITE is the sesquioxide of manganese, and crystallises in Case 9f. the Tetragonal system ; the specimens in the case from San Marcel are unusually fine.

CORUNDUM is the sesquioxide of aluminium, and crystallises Case 9f-h. in the Rhombohedral system.

Ranking next in lustre and in hardness to the diamond, it is, after the diamond, the most precious of stones. When pure it is the colourless variety known to jewellers as the *Lux* Case 9h. *Sapphire* : but with very minute traces of colouring ingredient it assumes the richest hues ; when red it is the true

## Sesquioxides

*Ruby*; when azure it is the *Sapphire*; while the yellow, green and purple varieties are known respectively to jewellers as the *Oriental Topaz*, *Emerald* and *Amethyst*; the prefix *Oriental*, though at first used to suggest that the stones are not the ordinary topaz, emerald and amethyst, but others of a similar colour coming from the East (India, Ceylon, Siam, Pegu, &c.), was afterwards understood to imply only the *excellence* of their characters. The *Star-stones* are a variety which, when placed in a strong light, show a six-rayed star; its position bears a simple relation to the crystalline form.

An extensive suite of faceted specimens of these varieties will be found in the case.

*Emery* is an opaque and impure corundum, but is still, from Case 9f. its great hardness, very valuable as a polishing material.

**HÆMATITE**, though very different from corundum in its Case 11a-c. external characters, corresponds to it very closely both in chemical type and in the fundamental angles of the crystalline form; it is a sesquioxide of iron and a very important ore.

Of *Specular iron*, the crystallised variety of hæmatite, a fine suite of specimens, more especially from Elba and Switzerland, is shown in the case; some of them have a characteristic tarnish which produces an effect of great beauty.

The massive variety known as *Red Hæmatite* is found in Case 11a. large deposits both in Lancashire and Cumberland; a large mass of it will be seen in a corner of the Pavilion. *Red Ochre* is an earthy variety of this mineral. *Red Ochre*, and also massive hæmatite when reduced to powder, are used as polishing materials.

**ILMENITE** is one of the ambiguous species of this series, and Case 11d. may be regarded either as an oxide of titanium and iron analogous to hæmatite, or as a titanate of iron. Its crystals have almost exactly the same angles as those of hæmatite; the proportions of the sesquioxides of iron and titanium in ilmenite are very variable. It is the mineral in which the element titanium was first discovered. Fine crystals, chiefly from Russia, are exhibited.

With this series are arranged the hydrated sesquioxides.

**GÖTHITE** is a hydrated sesquioxide of iron; unusually fine Case 12a. crystals of this mineral are shown from the Restormel and Botallack mines, Cornwall.



DIASPORE is the corresponding compound of aluminium, and Case 12bc.  
MANGANITE, that of manganese.

The last three minerals are very similar in their crystallographic as well as in their chemical type.

TURGITE is a common ore of iron, containing, in addition to Case 12d. the elements of hæmatite, 5 per cent. of water.

LIMONITE is one of the most important ores of iron, and Case 12de. when pure yields iron of superior quality; it has the same components as turgite, but contains about 15 per cent. of water. Reduced to powder it is, like hæmatite, used as a polishing material.

LIMNITE is the most highly hydrated oxide of iron, and Case 12f. contains as much as 25 per cent. of water.

BEAUXITE, or Bauxite, a hydrated oxide of aluminium and Case 12f. iron, is used for the manufacture of metallic aluminium on a large scale.

PSILOMELANE is a common ore of manganese, and generally Case 12fg. contains from 70 to 80 per cent. of the oxides of that metal: the oxide of barium present sometimes reaches 17 per cent.

WAD is a very similar mineral, but contains more water. Case 12h.

The last five minerals are not found crystallised.

Dioxides. PYROLUSITE, beginning the series of dioxides, is the most Case 11e. important ore of manganese. It is much used in the manufacture of glass for getting rid of the brown and green tints; also for bleaching purposes, and for the preparation of oxygen. The sulphate and chloride of manganese made from it are used in calico printing. Large and fine dendritic growths of pyrolusite are met with in the limestone of Solenhofen, in Bavaria; a good specimen is placed in the lower part of case 14.

CASSITERITE, or Tin-stone, is the ore of tin, of which metal it Cases 11f-13b. contains 79 per cent. The mines of Cornwall supplied the ancients with much of their tin. An extensive suite of crystals from Cornwall, Schlaggenwald and Ville d' Er will be found in the case.

Wood-tin is an uncrystallised fibrous form of the mineral, Case 13a. somewhat like dry wood in colour and structure.

*Stream-tin* is the ore in the form of sand, as obtained from Case 13ab. the beds of streams or the adjoining gravel.

ZIRCON contains the dioxides of both zirconium and silicon : Case 13bc. its crystals belong to the same system as those of cassiterite, and they have almost identical angles. Twin-growths are, however, as rare in zircon as they are common in cassiterite : the specimen from Renfrew in Canada is remarkably fine. When clear and without flaws it is one of the precious stones : one variety with peculiar red tints is the *Hyacinth* or *Jacynth*, while the colourless, yellowish and dull green are termed *Jargoon* : the colourless variety, owing to its high refractive power, approaches even the diamond in brilliancy : zircon is the heaviest of the precious stones. Fine cut specimens, and an almost unrivalled suite of Russian crystals, are shown in the case.

THORITE has a similar composition to zircon, the zirconium Case 13c. being here replaced by the rare metal thorium ; it contains from six to nine per cent. of water, and is probably a result of alteration. *Orangite* is a yellow variety of this mineral.

RUTILE, ANATASE and BROOKITE are chemically identical, Cases and are various forms of the dioxide of titanium. 13c-14a.

Fine specimens of rutile from Titanium Mount and Brazil, of anatase from Switzerland, and of brookite from North Wales and the Zillerthal, will be found in the cases.

We now come to a large group of specimens illustrating the manifold forms with which silica, the dioxide of silicon, presents itself in the Mineral Kingdom. The group begins with the crystallised varieties, tridymite and quartz, and ends with the amorphous variety, opal. Between these are arranged varieties regarded as mixtures of the crystalline and amorphous with each other, or also with oxide of iron, clay, or other impurities.

TRIDYMITE is a form of silica remarkable as crystallising Case 14b. in the Anorthic system, though the crystals are often so twinned that the growths present Hexagonal symmetry. It has the specific gravity of opal, which is less than that of quartz.

QUARTZ in its clear and transparent variety is the *Crystal* of Case 14bc. the ancients, and the *Rock-crystal* of modern times ; it is the *Brazilian Pebble* of the spectacle-makers. Several of the

specimens from La Gardette are remarkable not only for their clearness, but also as fine examples of a rare kind of twin-growth. The simple rhombohedra from Bristol and Onega, and the rare specimens showing a basal plane, are worthy of notice. A large ball, brought from Japan, illustrates this species in its purest form. The largest crystals are shown on separate stands in the Pavilion: one of them, a fine well-developed crystal, was presented in 1882 by Mr. C. S. Bement, of Philadelphia, U.S.A.

The history of the formation of rock-crystal is illustrated by some most interesting specimens enclosing other minerals.

Next follow the less clear varieties of quartz, beginning with the white. The *Potato-stone* from Clifton, near Bristol, in outer aspect is like its namesake, but when broken is found to be hollow and lined with crystals. *Cotterite*, an Irish quartz, has a peculiar pearly lustre.

To this succeed the smoky varieties, including the *Scotch Cairngorm* and *Occidental Topaz*. Next comes the *Amethyst*, sometimes yellow, sometimes purple; as a precious stone the latter lacks in brilliancy, but still is beautiful in colour. The *Amethyst* is distinguished from the other varieties of quartz by its rippled fracture and optical characters. Next follow the *Milky quartz*, *Rose-coloured quartz*, and the *Prase* of a leek-green colour. *Anturine quartz* is the name given to a variety spangled in general with mica. The *Quartz Cat's-eye* is a variety presenting the opalescence, but not the hardness or the brilliancy of the true *Cat's-eye* (chrysoberyl), an effect due to fibres of an asbestos-like mineral in the specimens from Ceylon, and to fibres of crocidolite in the blue, and of altered crocidolite in the brownish-yellow specimens from South Africa.

These are followed by a series of specimens illustrating peculiarities of form: cellular, hacked, spongy, fibrous (both parallel and radiated), and capped.

The so-called *Eisenkiesel*, or iron-flint, encloses and is coloured by the yellow or red oxide of iron.

Next comes *Jasper*, an uncrystallised coloured mixture of silica and clay, distinguished from ordinary quartz by its opacity and dull "earthy" fracture. It is of various colours, chiefly red, brown, yellow and green; and the colours are

arranged sometimes in a nodular form as in the Egyptian Case 13h. jasper, at other times in stripes, as in the Riband jasper.

The *Lydian-* or *Touch-stone*, by reason of its hardness and Case 15a black colour, has been used from remote ages to test the purity of the precious metals.

*Hornstone* is a variety of silica without evident crystallisation, Case 15a. and generally presents a more or less splintery fracture; but in one kind, *Flint*, the fracture is conchoidal, sometimes conical, Case 15b. as is well shown by the specimens in the case; in *Wood-stone* Case 15a. the particles of woody matter have been replaced by silica, but so slowly that the details of the original structure have been well preserved.

*Chalcedony* has a lustre nearly that of wax, and is either Case 15b-d. transparent or translucent: specimens from the Trevascus and Pednandrea mines, Cornwall, and from the Faroe Islands and Iceland, are worthy of special notice. The specimens from Uruguay enclose water.

The *Heliotrope*, or *Bloodstone*, is a green stone with red Case 16a. blood-like spots.

Next follow the *Plasma* and *Chrysoprase*, green stones: and the *Sard*, generally a brownish-red; as also the *Sardonyx*, its banded variety: all of them much prized by the ancients because, though hard and tough enough to resist ordinary wear and tear, they are more suited to the display of the engraver's skill than are the harder and more precious stones.

Then come the *Agates*, chiefly formed of thin layers of porous Case 16b-e. chalcedony of different colours, though the material of many of the white layers is a compact semi-opal. Most of the specimens are now brought from Uruguay, in South America, and are cut and polished at Oberstein, where, in former times, agates were got from the mountains of the district. Sometimes the layers are plane and parallel, and the stone is then an *Onyx*, useful as a material for cameos: or the bands of a section Case 16c. are arranged in sets of straight but zig-zag lines, and the stone is then called a *Fortification agate*: but in the ordinary agate the layers are variously curved: many examples of the variety of curve and colour will be seen in the case. The *Brecciated agate* from Kunnersdorf is especially worthy of notice.

The *Moss-agates*, or *Mocha-stones*, are varieties of chalcedony, Case 16e.

enclosing moss-like forms of oxides of manganese and iron and green earthy chlorite.

The *Carnelian* is a beautiful stone much valued by the engraver: its fracture has a peculiar waxy lustre, and is distinct from that of the sard, which is dull and hornlike. Case 16e.

We now come to the varieties of OPAL, the first being *Hyalite*, its purest form, generally clear and transparent as glass. Cases 16f-h, 15e.

Next follows the *Precious* or *Noble Opal*, conspicuous for its fascinating play of colours: by the side of those from the old Hungarian locality will be seen good examples from Queensland.

*Hydrophane* is remarkable as only being transparent and opalescent when its pores are filled with water.

The *Fire-opal*, from Mexico, varies from hyacinth-red to honey-yellow in colour. Case 16g.

Next to these are arranged other varieties, the green *Prase-opal*, *Common opal*, *Rose-opal*, *Wood-opal*, *Liver-opal*, *Semi-opal*, *Cacholong*, and also *Florite* with its beautiful pearly lustre. Cases 16h, 15e.

A series of specimens illustrating some of the forms of native silica, arranged and described by Professor Ruskin, is shown in a table-case of the Pavilion.

Other acid-forming oxides.

To quartz and opal, which terminate the series of the dioxides, succeed some other acid-forming oxides.

ARSENOLITE is the native sesquioxide of arsenic, crystallising in the Cubic system; the same compound artificially prepared, is known in commerce as white arsenic or arsenious acid, and is obtained on a large scale by roasting arsenical ores. Case 15f.

SENARMONTITE, the isomorphous sesquioxide of antimony, is represented by fine specimens from Algeria. Case 15f.

VALENTINITE has the same chemical composition as senarmon-tite, but its crystals belong to the Orthorhombic system. Case 15g.

SASSOLINE is the hydrated sesquioxide of boron (native boracic acid), found in the crater of Vulcano, one of the Lipari Islands. Case 15g.

CERVANTITE is a peroxide of antimony, and is a product of the decomposition of stibnite. Case 15h.

Section ii.  
—Oxygen-salts.  
Carbonates.

We next begin the section of oxygen-salts, the first class under which is formed by the carbonates. The long series of specimens of the anhydrous carbonates begins with those of which the crystals belong to the Orthorhombic system,

ARAGONITE is the calcium carbonate or carbonate of lime, and Case 17a-d. is identical in chemical composition with the mineral calcite, which crystallises in the Rhombohedral system. The coralloidal variety from Eisenerz is well represented in the case, and a large specimen of that variety will be found on a table at the end of the Gallery. The twin-growths from Case 17b. Girgenti, Hungary and Bohemia, are unusually fine.

WITHERITE is the barium carbonate; it is much used in Case 18a. the manufacture of plate glass, and, in France, for that of beet-sugar: the specimens from Fallowfield mine are remarkable twin-growths.

STRONTIANITE, the strontium carbonate, is the mineral from Case 18b. which most of the strontium nitrate is made for use in the manufacture of fireworks, owing to the fine crimson colour which it gives to the flame; it is at present much employed in the process of sugar refining.

CERUSSITE is the corresponding lead carbonate, and is Case 18b-d. identical in chemical composition with the manufactured "white-lead" of commerce: when abundant it is a valuable ore of the metal. The suite of crystallised specimens is a very fine one, but the specimens from Cardiganshire and Poullaouen, presented by Mr. J. Taylor and Mr. R. Simmons respectively, Case 18c. are worthy of special mention.

The isomorphism of calcium, barium, strontium and lead, is well shown by the above minerals, which are almost identical in their fundamental angles.

Next follow the Rhombohedral carbonates: on account of the isomorphism there is in several cases a gradual transition from one species to another.

First of the Rhombohedral carbonates is CALCITE. The Cases 18e-20c. clearest and purest variety is that from Iceland, thence termed *Iceland spar*. In this variety, owing to its clearness, was first remarked the fact that generally there are two images of an object seen through a cleavage-plate: whence it is sometimes called *Double-refracting spar*. It is largely used in optical instruments for affording polarised light.

The extraordinarily fine suite of specimens of calcite exhibited in the cases illustrates the almost endless variety of its crystalline form, and at the same time shows that the

variation is controlled by a definite law of symmetry. The specimens from Derbyshire and Cornwall are particularly worthy of attention. Two very large crystals from Iceland are shown in the Pavilion.

Specimens of twin-growths are shown in case 19b.

The so-called *Crystallised sandstone of Fontainebleau* is a Case 19d. curious variety of calcite enclosing a large quantity of grains of sand.

In case 20a, are shown stalactites and stalagmites, formed respectively on the roofs and on the floors or sides of caverns: they owe their origin to the slow dropping and evaporation of water, which has become charged with carbonic acid, and afterwards with carbonate of lime, in its course through limestone rocks.

These are followed by a group of specimens illustrating the Case 20bc. varieties of colour presented by this mineral.

Carbonate of lime occurs on a large scale as limestone and marble, varieties which will be found among the Rocks.

MAGNESITE is the corresponding carbonate of magnesium. Case 20d.

DOLOMITE is a carbonate of magnesium and calcium. The Case 20d-f. rock is used as an ornamental marble; when burnt it yields a durable cement. Both dolomite and magnesite were formerly largely used for the preparation of artificial Epsom salts.

ANKERITE contains the carbonates of calcium, magnesium and Case 20g. iron.

MESITITE is the corresponding carbonate of magnesium and Case 20h. iron.

CHALYBITE, or Spathic iron ore, is the carbonate of iron, Cases and is a most valuable ore of the metal. The series of crystal- 20h, 19e-g. lised specimens from Cornwall is very fine. Mixed with clay it is the most important English iron ore, *Clay-iron-stone*.

RHODOCROSITE is the carbonate of manganese: it is affected by Case 19gh. the action of light.

CALAMINE, the carbonate of zinc, is an important ore. The Cases crystallised specimen presented by Mr. R. Simmons, in 1836, 19h, 21a. is unique for excellence.

BARYTOCALCITE is a carbonate of barium and calcium, remark- Case 21b. able as crystallising in the Oblique system: a fine series of specimens is exhibited.

Hydrated carbonates. **CHESSYLITE** and **MALACHITE** are respectively the blue and green hydrated carbonates of copper, and are ores of that metal. An excellent suite of specimens of chessylite will be found in the case. Malachite is found in large masses; and by reason of the high polish which it takes and its beautiful markings, is much used for ornamental work of various kinds. Cases 21d, 22a-d.

Carbonates combined with chlorides, &c. **CROMFORDITE**, or Phosgenite, a compound of carbonate and chloride of lead, is represented by remarkable specimens from Matlock, and from Monte Ponì in Sardinia. Case 22d.  
**PARISITE** is a compound of the carbonates and fluorides of cerium, lanthanum and didymium; the suite of crystals from the Emerald mines of Muso is an extremely fine one for this rare mineral. Case 22d.

## Silicates.

The next class of oxygen-salts is that of the silicates, occupying no less than twelve cases. The minerals comprised in this large, varied and important class, are arranged in series distinguished by the type of oxide that characterises the bases of the silicate; in the first series are placed the silicates corresponding to monoxide-bases (ferrous oxide, magnesia, &c.); in the second, those of which the bases are sesquioxides; and in the third, the silicates of which the bases are of both kinds.

The anhydrous section of the first series begins with the orthosilicates.

Series i.—  
Monoxide  
bases.

A group of Rhombohedral minerals includes **WILLEMITE**, a zinc silicate, and **PHENAKITE**, a di-beryllium silicate; extremely fine specimens of the latter mineral from the Emerald mines of the Urals are shown in the case. Here also is arranged **DIOPHASE**, fine crystals of which are now rarely met with; it is a hydrogen-copper silicate. Case 22e.  
Case 22ef.

Passing to the next group which consists of Orthorhombic minerals, we find **TEPHROITE** a manganese silicate, and **OLIVINE** a magnesian-ferrous silicate of the series. Case 22f.

**OLIVINE** in its clear transparent forms is one of the less hard and least valued of the precious stones; when of a yellow colour it is known as the *Chrysolite*, while the pistachio-green variety is the *Peridot* of jewellery. Fine crystals and faceted specimens are shown.

**HUMITE**, a highly basic fluo-silicate of magnesium, is arranged here: the specimens are numerous and fine. Case 22g.



GADOLINITE, also one of the more basic silicates, chiefly of Case 22gh. yttrium, iron and beryllium, is represented by fine crystallised specimens, more especially from Hitteröe.

The minerals ENSTATITE, BRONZITE and HYPERSTHENE, crystal- Case 22a. lising in the Orthorhombic system, begin the metasilicates; they are silicates of magnesium and iron, the relative proportions of the metals varying in the different minerals.

The extensive AUGITE and HORNBLENDE groups now follow; Cases though the chemical type is the same for all the members 21e-24c. of these groups, the bases vary much both in nature and relative proportion, and thus give rise to so many varieties that we must refer the visitor to the text-books of Mineralogy for their discussion.

SPODUMENE, essentially a silicate of aluminium and lithium, Case 23a. is represented by very fine large specimens, one of the best being shown in the lower part of the case; a rare emerald-green variety from North Carolina, U.S.A., *Hiddenite*, of which both crystals and a clear faceted specimen are exhibited, has been lately introduced into jewellery as a precious stone.

CROCIDOLITE is a silicate of iron and sodium; it is an asbestos- Case 24a. like mineral, interesting as being the fibrous substance enclosed in the South African blue quartz cat's eyes.

ASBESTOS is the only variety of hornblende used in the Case 24c. arts: it is found in long fibres, and in some of its varieties is so flexible that it can be woven into gloves and other articles; examples will be found among the worked specimens in the Pavilion. The term asbestos, *unquenched* or *unquenchable*, was applied to the mineral by the ancient Greeks because, owing to its being unaltered by heat, wicks made of it were used in maintaining the sacred perpetual fires of their temples. Napkins of asbestos were cleaned by being thrown into the fire; asbestos cloth was also used in the process of cremation to keep the ashes of the body distinct from those of the fuel. It is now much employed for lining iron-safes, as a packing for steam-pipes and boilers, and in gas-stoves.

JADE, or Nephrite, is a mineral assigned to this group, and Case 24d. is essentially a silicate of magnesium and calcium. This mineral has few known localities, and it has been difficult to answer the question as to whence the older workers of jade can have obtained their material; the prehistoric jade was got partly

from China, partly from the Kuen Lun Mountains on the northern border of Thibet; all the white comes from the former country.

The various shades of colour, and the beautiful polish which this tough mineral will take, are illustrated by specimens in the case. The worked specimens from New Zealand, of which there are several in the collection, are now rare.

On a table at the end of the gallery will be found a large worked mass of an olive-green colour, brought to England by Lieut.-General Kyd, and presented to the Trustees in 1830 by Mr. Thomas Wilkinson. Both in shape and colour it resembles the Ganges tortoise: it was found near Allahabad at the bottom of a tank or pond, into which it had probably been thrown by its worshippers to prevent its falling into the hands of the enemy. An immense waterworn mass found some years ago near the graphite mines of M. Alibert, to the west of Lake Baikal, in Asiatic Russia, is shown in the Pavilion.

One of the characters useful for the recognition of jade is its specific gravity: this is generally about 3·0 in the green, and about 2·9 in the cream-coloured varieties.

WOLLASTONITE is the calcium metasilicate.

Case 24e.

RHODONITE, the manganese metasilicate, crystallises in the Anorthic system; the specimens of richer colour are in Russia used for ornamental work.

Case 24ef.

BABINGTONITE has the same chemical type and crystallises in the same system as rhodonite, but is a silicate of calcium, iron and manganese; it was formerly worked in Cornwall as an iron ore.

Case 24f.

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APOPHYLLITE belongs to the hydrated section of this series; it is a hydrated silicate of calcium and potassium. Extraordinarily fine specimens, got in blasting the rocks during the construction of the Bombay and Poonah railroad, were presented by Mr. J. J. Berkley, in 1860; most of them are shown in a wall-case of the Pavilion.

Cases 24f-h, 23e.

MEERSCHAUM is the light soft porous mineral used for tobacco-pipes: it is a hydrated silicate of magnesium.

Case 23g.

TALC is another hydrated silicate of magnesium, and was formerly used in the manufacture of porcelain. The amorphous form, *steatite* or *soapstone*, is worked by the

Case 23gh.

Chinese into ornaments, of which examples are shown in the Pavilion; it is also used for gas-burners, electric insulators, linings for stoves, &c.

SERPENTINE is another hydrated magnesium silicate: the ease with which it is worked and takes a good polish, its green colour and varied markings render it much sought for as a material for fire-places, tables, and other indoor work: exposed to the weather it soon loses its polish. Occurring on a large scale, it is best considered among the Rocks; only specimens illustrating the simple mineral are shown in the case. Case 25a.

HEMIMORPHITE, a hydrated silicate of zinc, is an important ore. Case 25b.  
 CHRYSOCOLLA is a hydrated silicate of copper. Case 25c.



Series ii.—  
 Sesqui-  
 oxide bases.

The second series, consisting of minerals in which the bases are sesquioxides, commences with topaz, a silicate of aluminium, containing also a considerable percentage of the element fluorine.

TOPAZ in its clear varieties is one of the precious stones. A large series of specimens illustrating the varieties of crystalline form will be found in the case; those from the Urulga river in Siberia are remarkably fine examples of crystalline development; they are of a delicate brown colour, but are kept covered up as the action of light speedily bleaches them. The yellow crystals from Brazil assume a peculiar pink colour when heated, and are then known to jewellers as *Burnt* or *Pink topaz*; some of these will be found in case 26a; crystals with the same tint are sometimes found in Nature. The crystals from Saxony are of a paler yellow colour, which they entirely lose on being heated. Topaz has a very easy cleavage, and readily becomes electric on being rubbed or heated. Cases 25c-26b.

ANDALUSITE is a silicate of aluminium. Some of its transparent crystals are very dichroic, as is well shown by a faceted specimen in the case. Case 26b.

STAUROLITE is a silicate, the bases of which consist essentially of the sesquioxides of aluminium and iron; it is remarkable for its twin-growths, and is found almost exclusively in clay-slates and mica-schists. Case 26c.

KYANITE has the same chemical composition as andalusite, but crystallises in the Anorthic instead of the Orthorhombic Case 26cd.

system. The specimen from Chesterfield, Massachusetts, is Case 26d. unusually fine.

FIBROLITE also has the same chemical composition. Being Case 26d. extremely tough and yet not difficult to work, it was manufactured into stone implements in prehistoric times, particularly in parts of France.

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Series iii.—  
Monoxide  
and sesqui-  
oxide bases.

The third series of silicates is constituted of those in which monoxides and sesquioxides together act as bases.

First of these is the Garnet group, the members of which all crystallise in the Cubic system but vary indefinitely in chemical composition, though always in accordance with a definite typical formula.

GARNET belongs to the group of precious stones; when the red is tinged with violet, it is the *Almandine* and the *Syrian garnet* (from Syriam in Pegu), and when cut *en cabochon*, the *Carbuncle* of jewellery (Case 26f); the *Cinnamon stone* or *Essonite* is yellow (Case 26e); the *Pyrope* and the *Bohemian garnet* are blood-red (Case 26h). *Uwarowite* is a green chrome-garnet (Case 26h). In the case will also be found some of the green garnets from the gold washings of the river Bobrowska, in Russia (Case 26a). Garnet often acts on the magnetic needle; it is one of the heaviest and most common of the precious stones. Case 26e-h.

IDOCRASE crystallises in the Tetragonal system; though Case 25ef. essentially a silicate of calcium and aluminium, the percentages of iron and magnesium in its different varieties are sometimes very high.

SARCOLITE also crystallises in this system, and is noticeable as Case 25g. representing a kind of hemihedry of which there are few examples. In addition to the elements of idocrase it contains sodium.

SCAPOLITE also is Tetragonal in its symmetry; like idocrase it Case 25gh. is a silicate of calcium and aluminium.

LEVERITE is a silicate of calcium and iron, the latter element Case 27a. being present both as monoxide and sesquioxide; a series of good crystals from Elba is exhibited.

JADEITE is essentially a silicate of sodium and aluminium. Case 27ab. It is one of the green stones which, under the name of jade, are wrought into ornaments in China; from that mineral, however, it is distinguished by its chemical composition, structure and higher specific gravity, the latter ranging from 3.1 to 3.4.

**EPIDOTE** is essentially a silicate of calcium, iron and aluminium. Fine specimens from the Untersulzbachthal are in the case. Case 27cd

**DICHOITE** is a silicate of magnesium, iron and aluminium; its transparent variety is the *Saphir d'eau* of jewellery, and is remarkable for the variation of its colour according to the direction in which it is looked through; the polished specimens in the case illustrate this character. Case 28a.

**MICA** is the name given to a group of minerals differing much from each other in chemical composition and optical properties, but having as a common character an easy cleavage in a single direction, and thus affording plates remarkably thin, transparent, tough and elastic. One of these minerals, muscovite, has been used in Russia in place of glass for windows; it is now in common use for lanterns and stoves, not being so easily cracked as glass by change of temperature: it is still known in commerce as *talc*, a term applied to it by the older mineralogists.

In the Micas the oxides of potassium and aluminium are almost invariably present; **PHLOGOPITE** contains a considerable proportion of magnesium; **BIOTITE** contains both magnesium and iron; **LEPIDOMELANE** much iron and little magnesium, much of the aluminium being replaced by iron; **ASTROPHYLLITE** contains much titanium, zirconium, &c., and little aluminium; **MUSCOVITE**, much potassium and aluminium; **LEPIDOLITE** contains small proportions of lithium, rubidium and caesium, and is an important source of lithium and rubidium salts. Case 28a.  
Case 28bc.  
Case 28c.  
Case 28c.  
Case 28de.  
Case 28e.

**LEUCITE** is a potassium-aluminium silicate: its crystals were long regarded as presenting typical forms of the Cubic system, but vom Rath has, after minute examination, shown that the symmetry is really that of the Tetragonal; Klein has lately discovered that its optical characters indicate a sudden change to Cubic symmetry at a temperature probably below the melting-point of zinc. A very fine transparent crystal will be seen in the case. The mineral has only been found in volcanic rocks. Case 28e

**NEPHELINE** is a silicate of sodium and aluminium with some potassium; its crystals present Hexagonal symmetry. Case 28f.

We now come to the group of **FELSPARS**, the most important of rock-forming minerals; for details of their characters we must refer the visitor once more to the text-books. Their crystals, though belonging to two different systems, the Oblique and Anorthic, present a great similarity of form; they have two

easy cleavages, at right angles in the Oblique and nearly so in the Anorthic crystals; they are a little less hard than quartz. The metals of the monoxide bases are calcium, sodium, potassium, and in one species barium; the sesquioxide is that of aluminium.

ANORTHITE, represented by excellent crystals from Vesuvius Case 28f-h. and other localities, is a lime-felspar.

LABRADORITE is a lime-soda felspar, and is remarkable for Case 28h. the change of colour of the light reflected from it in different directions.

OLIGOCLASE is a soda-lime felspar; a superb crystallised Case 27e. specimen from Switzerland is shown in the case.

ORTHOCLASE, an Oblique potash-felspar, is represented by a Case 27e-h. series of very fine specimens.

MICROCLINE is an Anorthic potash-felspar, closely simulating Case 29a. orthoclase in crystalline form. *Amazon-stone* is a green variety of this mineral; its colour is destroyed on heating.

ALBITE is a soda-felspar: *Pericline*, one of its varieties, is Case 29ab. represented by very fine specimens.

Leaving the Felspar group we now come to BERYL, a silicate of aluminium and beryllium, presenting Hexagonal symmetry.

*Emerald*, its bright green variety, is one of the most valued Case 29c. of precious stones. It was in ancient times worked in Egypt, as is proved by the rough specimens found in the old workings by Sir Gardner Wilkinson and presented by him to the Museum. Emeralds are found in the Urals; but the locality for the finest stones has for a long time been that of Muso, about seventy miles from Santa Fé de Bogotá, in S. America; excellent specimens are shown in the case. Lately emeralds, though not of a very good colour, have been discovered in the United States; some of the best of those found are here shown.

The remaining varieties of this species are illustrated by a Cases large suite of crystals, those from Mursinsk, in the Urals, being 29c-30a. particularly fine. Facetted specimens of the colourless beryl, and also of the bluish-green beryl, known in jewellery as *Aquamarine*, are exhibited.

EUCLASE is a silicate of aluminium, beryllium and hydrogen, and Case 30b. crystallises in the Oblique system: a fine, almost unique, suite of crystals of this rare mineral is exhibited. Attempts have been made to introduce this mineral into jewellery on account of its lustre and hardness; but for this purpose its brittleness and easy cleavage make it unsuitable.

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We now come to the remaining hydrated silicates, the first series of which consists of those minerals in which the bases are sesquioxides.

In this series are the various hydrated silicates of aluminium, including kaolinite, halloysite, the unsatisfactory group of clays, pyrophyllite, &c.

KAOLINITE is a result of decomposition of the felspar of granite, Case 30b. and, under the name of *China-clay*, the mixture of kaolinite and quartz is extensively used for the manufacture of porcelain.

As a first group in the series of hydrated silicates having both monoxides and sesquioxides for bases, we come to the Zeolites, so called because when fused they appear to *boil*, owing to the escape of the water.

PREHNITE has for bases alumina and lime; the proportion of water is only about 4.4 per cent. Case 30ef.

NATROLITE has for bases alumina and soda; in MESOLITE the soda is partly, and in SCOLECITE wholly, replaced by lime: Case 30gh. fine specimens from Iceland and India are shown. Case 29ef.

EDINGTONITE is a hydrated silicate of aluminium and barium; Case 29g. it is an exceedingly rare mineral, and has only been found as small crystals in the amygdaloid of the Kilpatrick Hills, near Glasgow.

ANALCIME has for bases alumina and soda; the specimens of this mineral furnish very typical examples of the symmetry of the Cubic system. Case 29gh.

POLLUCITE is remarkable as being a hydrated silicate of aluminium and of the rare element caesium; the water amounts to only 2.4 per cent. Case 29b.

LAUMONTITE has for bases alumina and lime; exposed to dry air the specimens fall to powder, owing to loss of water. Case 29h.

CHABASITE has the same bases as laumontite; its crystals, though really belonging to the Rhombohedral system, are almost cubical in form. Case 31b.

HARMOTOME, a hydrated silicate of aluminium and barium, is represented by very fine specimens from Strontian and Andreasberg; the cruciform growths of this mineral are very characteristic. Case 31d.

STILBITE and HEULANDITE are also hydrated silicates, having for bases alumina and lime, and crystallising respectively in the Orthorhombic and Oblique systems; an exceedingly fine suite of specimens from Iceland, Faroe Is. and India, is shown in the case. Case 32a-d.

We now leave the Zeolites and come to the Chlorite group, the members of which are very similar to the Micas in their general characters, but have water in their composition.

PENNINE, has for bases alumina and magnesia, with some oxide of iron. Its crystals are Rhombohedral in symmetry. Case 32e.

VERMICULITE is a name given to a series of minerals which possess the curious property of exfoliating when heated, the volume being thereby increased sometimes as much as tenfold. Case 32e.

CLINOCHLORE has a very similar composition to pennine, but its crystals are proved by their optical characters to belong to the Oblique system; a superb specimen from Achmatovsk is exhibited. Case 32f.

RIPIDOLITE has the same components as pennine and clinocllore, but contains a large percentage of the monoxide of iron, and possibly belongs to the Rhombohedral system. Case 32g.

MARGARITE is a hydrated silicate of alumina and lime. Case 32h.

Leaving this group, and at the same time the hydrated aluminium silicates, we come to

CRONSTEDTITE, a hydrated silicate having for bases the sesquioxide of iron, and the monoxides of iron and manganese: unusually well crystallised forms of this Rhombohedral mineral are in the case. Case 31e.

These are succeeded by a series of uncrystallised silicates of more or less uncertain composition. Case 31fg.

Silicates  
combined  
with  
sulphides,  
chlorides,  
&c.

Leaving the silicates proper, we next come to minerals containing silicates in combination with other compounds, the latter containing no oxygen.

DANALITE and HELVINE are compounds of silicates with sulphides. Case 31gh.

SODALITE is a sodium-aluminium silicate combined with sodium chloride; it crystallises in rhombic dodecahedra. Case 31h.

PYROSMALITE is a silicate of iron and manganese, containing also chlorine and water; a fine suite of specimens will be found in the case. Case 31h.

Silicates  
combined  
with  
borates.

These are succeeded by minerals in which silicates are associated with other compounds of oxygen.

First are arranged the minerals in which silicates are associated with boric-oxide or borates.

TOURMALINE is a mineral of which the crystals belong to the Rhombohedral system, and are remarkable as presenting a difference in the development of the faces at the two ends of the prism. This difference in the crystalline development of the two ends is accompanied by a difference in electrical behaviour; for when a crystal of tourmaline is being warmed or cooled, not only does it become electric and first attract and then repel light bodies in the same way as does amber, but one end of the crystal is opposite in electrical character to the other. Tourmaline of certain colours is much valued for its Case 33a-c.



property of acting as a polariser on common light, a plate of the proper thickness absorbing one of the two rays produced by the double refraction. Tourmaline is very variable in colour and also in chemical composition.

Some of its varieties when free from flaws are classed with the precious stones. Among these is the pink variety called *Rubellite*. Two very fine specimens of rubellite from Ava Case 33a. are shown in the case; one of them, remarkable for its size and shape, was brought from that country by Colonel Symes to whom it had been presented by the King; the other, not so large but of a deeper colour, was presented in 1869 by Mr. C. S. J. L. Guthrie. On a table in the Pavilion will be found a specimen from Elba, showing a large group of pink crystals still attached to the rock.

The pink-and-green tourmalines from Paris, Maine, U.S.A., Case 33a. are among the more beautiful of the mineral products of the United States.

AXINITE is a borosilicate, with alumina as the sesquioxide, and Case 33d. lime and ferrous oxide as the monoxide bases; the suite of specimens is unusually fine.

DANBURITE and DATHOLITE are borosilicates of calcium, the Case 34a. latter containing about 5·6 per cent. of water: worthy of special mention are the specimens of Danburite from Berg Scopi, and of Datholite from Toggiana and the Harz.

Silicates combined with sulphates. HAÜYNE is a compound silicate and sulphate having for Case 34b. monoxide bases soda and lime, and for sesquioxide base, alumina; the rich blue variety is the *Lapis Lazuli* of jewellery, and is brought from Persia, China, Siberia and Bokhara, generally in the massive state. A large crystal in the case is worthy of attention.

When powdered, lapis lazuli furnished the once costly pigment *ultramarine*; through the discovery of a method of producing an artificial and cheap form of the same material, the use of the mineral as a pigment has been quite superseded.

Titanates,  
&c.

We next come to a series of minerals not only themselves of rare occurrence, but having in several cases for constituents some of the rarest elements, namely the titanates, tantalates, niobates, zirconates, &c., both singly and in association with each other, and with silicates.

Among these we may call attention to the specimens of PEROFSKITE, TSCHIEFFKINITE, EUDIALYTE, SPHENE, COLUMBITE, SAMARSKITE, FERGUSONITE, PYRRHITE and ÆSCHYNITE, as being especially remarkable either for their excellence or their rarity.

Molybdates  
and  
tungstates.

The next class is that of molybdates and tungstates.

WULFENITE is the molybdate of lead, and is represented by fine specimens from the United States and Carinthia. Case 33ef.

SHEELITE and STOLZITE are respectively the tungstates of calcium and lead; of scheelite a fine suite, including specimens from Cumberland and Devon, is shown. Case 33fg.

WOLFRAM is the tungstate of iron and manganese, and is the chief source of the tungstates of commerce. Case 33h.

Chromates  
and  
sulphates.

CROCOISITE is a mineral belonging to the next class, and is a chromate of lead; it has the same chemical composition as the artificial pigment *chrome yellow*. As this mineral is affected by the light, the fine series of specimens from Beresovsk and Brazil is kept in the drawers. Case 35a.

ANHYDRITE is the anhydrous sulphate of calcium. The crystal from Hallein is an exceptionally good one. Case 35bc.

CELESTINE is the corresponding sulphate of strontium; rare blue crystals from Hungary, and excellent specimens from Bristol and Sicily are in the case. Case 35cd.

BARYTES, or Heavy spar, is the sulphate of barium; it is a very heavy mineral, being  $4\frac{1}{2}$  times as heavy as its own volume of water. The suite of specimens from British localities is very fine, and pre-eminently so are those from Wheal Mary Ann. A remarkably clear specimen from Przibram will also be found in the case. The mineral is ground up and mixed with white lead for use as a paint; barium sulphate is also manufactured on a large scale for the same purpose and is then known as *permanent white*. Case 36a-d.

ANGLESITE, the sulphate of lead, is represented by fine specimens from Anglesey and Derbyshire, and also from Pennsylvania and Monte Poni. Case 36ef.

LANARKITE also is a sulphate of lead; the specimens in the case are amongst the finest known of the species. Case 36g.

We now pass on to the hydrated sulphates.

Hydrated  
sulphates.

SELENITE, or Gypsum, is the hydrated sulphate of calcium. Its crystals belong to the Oblique system; by reason of the easy cleavage parallel to the plane of symmetry it may be obtained in very thin plates, which are much used in polarising apparatus. Case 36f-h.

Selenite, when heated, gives up its water of crystallisation and falls to a powder, known as "Plaster of Paris;" when moistened the powder combines again with the water and forms a coherent solid. Fine specimens from Bex and Sicily are in the case, and a very large crystallised specimen from Reinhardsbrunn in Gotha, a gift from H.R.H. the late Prince Consort, will be found in the Pavilion. *Gypseous alabaster* is a massive variety of selenite; owing to its whiteness, fine texture and softness, it is largely used as a material for statuettes and other ornaments; the *Oriental alabaster* is a harder substance, stalagmitic calcite. Case 36h.

EPSOMITE is the hydrated sulphate of magnesium, and is known in commerce as Epsom salts: it is largely used in medicine and in dyeing. Epsom salts are now largely manufactured from Case 36h.

KIESERITE, another hydrated sulphate of magnesium, which occurs in beds at Stassfurt; it is only slightly soluble in water. Case 36h.

MELANTERITE is a hydrated sulphate of iron. The iron sulphate of commerce (green vitriol), largely used for dyeing and tanning, and for the manufacture of ink and Prussian blue, is chiefly manufactured from pyrites and pyrrhotite. Case 35e.

CHALCANTHITE is a hydrated sulphate of copper. The 'Blue Copper,' or 'Blue Vitriol' of commerce is chiefly manufactured from copper turnings and roasted copper ores; it is much used in dyeing and calico printing. Case 35fg.

BROCHANTITE, WARINGTONITE and LANGITE are also hydrated sulphates of copper. The crystals of langite from Botallack and Fowey Consols are twinned like those of aragonite. Case 35g.

LETT SOMITE, a beautiful velvet-like mineral, is a hydrated sulphate of copper and aluminium: remarkable specimens are shown. Case 35h.

ALUM, a hydrated sulphate of potassium and aluminium, has long been valuable for dyeing purposes. The greater part of the alum required for commerce is, however, obtained artificially from alumstone and shale. Case 37a.

ALUNITE, or Alumstone, is another hydrated sulphate of these metals: it occurs at the famous mines of Tolfa, in the neighbourhood of Rome, and from it a very pure alum is prepared by repeated roasting and lixiviation. Case 37a.

LINARITE is a hydrated sulphate of lead and copper: splendid specimens from Roughten Gill are exhibited. Case 37b.

Sulphates  
combined  
with other  
salts.

CONNELLITE is a compound of sulphate with chloride of Case 37b.  
copper.  
CALEDONITE is a compound of sulphate of lead with the Case 37bc.  
carbonates of copper and lead.  
LEADHILLITE and SUSANNITE are compounds of sulphate with Case 37c.  
carbonate of lead.  
The specimens of the last five minerals shown in the case are  
amongst the finest known.

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Borates.

LUDWIGITE is a borate of iron and magnesium, and is very Case 37c.  
similar in appearance to the dark-coloured fibrous tour-  
maline.  
RHODICITE, an extremely rare mineral, is probably an alkaline Case 37c.  
boro-aluminate: it was found near Ekaterinburg as minute  
crystals on rubellite.

Hydrated  
borates.

BORAX is a hydrated borate of sodium. It is much used as Case 37c.  
a flux, also in the process of soldering, and in the preparation  
of easily fusible enamels. It was formerly carried over the  
Himalayas from a lake in Thibet, but is now extensively  
prepared from the boracic acid of the lagoons in Tuscany.  
Fine crystals are exhibited from the Borax Lake of California,  
which supplies the whole of the United States with borax.

Borates  
combined  
with  
chlorides,  
&c.

BORACITE is a borate of magnesium combined with chloride of Case 37d.  
magnesium, the proportion of the latter amounting to 11 per  
cent. On account of its remarkable electrical and optical  
properties, and the relation of these to the crystalline form,  
boracite has long been extremely interesting to the mine-  
ralogist.

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Nitrates.

NITRE, or Saltpetre, the nitrate of potash, belongs to the Case 37d.  
class of nitrates. It is used in the manufacture of gunpowder,  
and of nitric and sulphuric acids.

NITRATINE, or Soda nitre, is the nitrate of soda: in the Case 37d.  
Desert of Atacama it is found in beds extending for many miles.  
It is used for the preparation of nitric acid and of saltpetre.

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Phosphates,  
arsenates  
and  
vanadates.

We now come to the minerals which contain phosphates,  
arsenates and vanadates; nearly all are hydrated.  
HAIDINGERITE and PHARMACOLITE are hydrated arsenates of Case 38b.  
calcium; the specimen of the former mineral, from the  
Allan-Greg collection, is unique.

## *Phosphates, arsenates and vanadates.* 111

**CHURCHITE** is a hydrated phosphate of cerium and didymium : Case 38b. of this rare mineral one of the specimens in the case is the finest known.

**RHABDOPHANE**, a blende-like mineral, to which attention was Case 38b. first called by Mr. W. G. Lettsom, is a hydrated phosphate of cerium, lanthanum, didymium and yttrium. Its precise Cornish locality is unknown ; the same mineral has been lately discovered at Salisbury, Conn. U.S.A., and described under the name Scovillite.

**VIVIANITE** is a hydrated phosphate of iron : a fine series of Case 38bc. crystals is shown from Wheal Jane : it is sometimes found with fossil shells and bones, having been a result of the decomposition of the organic matter.

**ERYTHRITE** is a hydrated arsenate of cobalt, found in beautiful Case 38c. crystals.

**PHARMACOSIDERITE** and **SCORODITE** are hydrated arsenates of Case 38de. iron : an excellent suite of each of these minerals is shown.

**WAVELLITE** is a hydrated phosphate of aluminium. Case 38ef.

**ANDREWSITE** is a hydrated phosphate of iron and copper : those Case 38g. in the case are almost the only specimens known.

**CALAITÉ**, or *Turquoise*, is a hydrated phosphate of aluminium ; Case 38g. it owes its blue or green colour to the presence of small quantities of salts of copper and iron. It does not occur crystallised. Being as hard as felspar and taking a good polish, it has been much prized in jewellery under the name of *Oriental Turquoise* ; that which comes into the market is chiefly brought from the turquoise mines, not far from Nishapur in Persia. A fine large mass from a mountainous district in China is shown in the case. Some specimens of the turquoise found by Major Macdonald in the neighbourhood of Mount Sinai are exhibited.

**LIBETHENITE** is a hydrated phosphate, and **OLIVENITE** the Case 37ef. corresponding arsenate of copper.

**LUDLAMITE** is a hydrated phosphate of iron : an unrivalled Case 37g. suite of specimens from Wheal Jane, its only certain locality, is shown.

**CLINOCLASE**, a hydrated arsenate of copper, is represented by Case 37h. good specimens.

**ERINITE** also is a hydrated arsenate of copper : of this Case 37h. rare species a fragment of the only example known is exhibited.

**CHALCOPHYLLITE** is another hydrated arsenate of copper ; fine Case 37h. examples are in the case.

## 112 *Phosphates, arsenates and vanadates.*

**LAZULITE** is a hydrated phosphate of aluminium and magnesium: the specimens from Werfen and Graves Mt. are worthy of special notice. Case 39b.

**CALCO-URANITE** is a hydrated phosphate of uranium and calcium, and is represented by very fine specimens from St. Symphorien. Case 39c.

**URANOCIRCITE** is a similar compound in which the calcium is replaced by barium: the fine Falkenstein specimen in the case was presented by Mr. A. H. Church in 1881. Case 39c.

In **CUPRO-URANITE** the calcium is replaced by copper: the Cornish suite is an excellent one. Case 39d.

**CHILDRENITE** is a hydrated phosphate of aluminium, iron and manganese: a remarkably fine suite, including the largest crystal known, is in the case. Case 40a.

**LIROCONITE** is a hydrated phosphate of aluminium and copper. Case 40a.

Phosphates,  
&c.,  
combined  
with  
chlorides,  
&c.

The next group is composed of minerals in the constitution of which phosphates, arsenates and vanadates, are associated with chlorides or fluorides.

**APATITE** is a mineral in which phosphate of calcium is associated with chloride or fluoride of the same metal. Among the remarkably fine crystals exhibited may be specially mentioned those from Kiriabinsk, Knappenwand, Schwarzenstein and Bovey Tracey, the best specimens from the latter locality being in the lower part of the case. *Phosphorite*, *Sombrierite* and *Osteolite* are massive varieties of apatite. When abundant it is valuable as an agricultural manure; when used for this purpose it is first treated with sulphuric acid. Case 40b-d.

**PYROMORPHITE** is a corresponding compound in which the calcium is replaced by lead; and **MIMETESITE** has a similar constitution to that of pyromorphite, the phosphoric acid being replaced by arsenic acid: excellent suites of both these minerals are shown, but the specimen of mimetesite presented in 1836 by Mr. Simmons is an extraordinary one. Case 40e.

**VANADINITE** is the corresponding vanadate of lead, and is also represented by a remarkable series of specimens. Case 40g.

**WAGNERITE** is a phosphate and fluoride of magnesium. Case 39e.

Oxalates.

**WHEWELLITE**, a hydrated oxalate of lime, is represented by a portion of what was long the only specimen known: the crystals of whewellite are small and associated with crystallised calcite. It was presented by Mr. W. G. Lettsom in 1870. The mineral has been recently found near Dresden. Case 39h.

**SUPPLEMENT.****Organic Compounds.**

As a supplement to the collection of simple minerals, there is arranged, in cases 41 and 42, a group of natural substances which either belong or are closely related to the Mineral Kingdom, although in their formation organised matter has played a very important part. Consisting as these substances do, either wholly or in part of carbon and hydrogen, they form a group sometimes known as that of the Hydro-carbons.

The most important members are coal and amber.

COAL, in most of its varieties, gives structural evidence of its Case 41ab. vegetable origin: its chemical composition depends on the more or less complete nature of the change which has taken place, and is thus not so definite as in the minerals of the preceding divisions. In the variety called *anthracite* all traces of the original organised structure have disappeared.

AMBER, in ancient times regarded as one of the precious Case 42cd. stones, is likewise of vegetable origin. It is a fossilised resin, chiefly derived from trees analogous to the present pine: its originally viscous condition is sufficiently proved by the insects which are sometimes found enclosed in it. Some of the ambers from Sicily shown in the case, when placed in the sun-light, present in a remarkable degree the peculiar optical character termed fluorescence.



## THE PAVILION.

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In the Pavilion are exhibited :

1. The Collection of Meteorites (see the special guide).
2. Rocks (not yet arranged).
3. Specimens too large for exhibition in the table-cases of the Gallery.
4. A series of specimens arranged by Prof. John Ruskin to illustrate some of the forms assumed by native silica.

Of the large specimens the following are worthy of special notice :—

A fine specimen of Stibnite from Japan. :

A group of British and Indian minerals, arranged in the centre of the long wall-case : including

Beautiful specimens of Apophyllite, Stilbite and Heulandite, from the Syhadree Mountains : obtained during the construction of the Bombay and Poonah railroad, and presented in 1860 by Mr. J. J. Berkley.

A large specimen of crystallised Salt from the Punjab, presented in 1870 by Mr. R. Brandreth.

A large mass of Sard from India.

Beautiful specimens of Calcite from Wheal Wrey and Herodsfoot mine, Cornwall, and Wheal Friendship, Devon ; of Fluor, from Weardale in Durham, and Menheniot and Herodsfoot mines, Cornwall ; of Harmotome from Strontian ; and of Celestine from Pylle Hill, near Bristol : a specimen of Barytes from Babbacombe, Devon, presented in 1837 by Mr. G. Payne.

A table-top of Serpentine (Connemara marble) presented in 1826 by Mr. Richard Martin : resting on it is part of a large nodule of iron, extracted by Professor Nordenskiöld from the basalt of Ovifak in 1870, and presented by him to the Trustees.

A table-top made of polished pebbles from Italian streams : upon it is placed a specimen of albite-granite from San Piero, Elba, with many crystals of the pink variety of Tourmaline still in their natural positions on the rock.



On another table are placed

A polished specimen of Jasper Conglomerate from Kaimur, Bandalkhand, India.

A large polished specimen of Derbyshire Fluor.

A large Agate, from Uruguay, cut in two and polished.

On a table in the corner is an immense specimen of crystallised Galena from the Great Laxey mine, Isle of Man.

Beneath the table is a large mammillary mass of Hæmatite, from Lancashire.

In a special case are placed

1. A fine specimen of Selenite from Reinhardtsbrunn: presented in 1847 by H.R.H. the late Prince Consort.

2. Two fine crystals of Iceland spar: one of them has been cleaved to show the two images of a cross painted on the opposite side of the specimen.

On a table in the next corner is an immense specimen of green Jade from Battugol in Asiatic Russia.

On another table is a fine specimen of crystallised Calcite from Andreasberg.

On separate stands are placed several isolated crystals of Quartz, remarkable for their size, colour or transparency; one of them, a long doubly-terminated crystal, was presented in 1882 by C. S. Bement, Esq., of Philadelphia, U.S.A.



# ALPHABETICAL INDEX

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Alexandrite . . . . .	9e	89	Beryl . . . . .	29c	104
Allemontite . . . . .	2g	77	Biotite . . . . .	28b	103
Almandine . . . . .	26f	102	Bismuth . . . . .	2g	77
Alum . . . . .	37a	109	Bismuthite . . . . .	6f	83
Alunite. . . . .	37a	109	Black copper . . . . .	10c	88
Amalgam . . . . .	2f	76	Blacklead . . . . .	1h	79
Amazon-stone . . . . .	29a	104	Blende. . . . .	4b	80
Amber . . . . .	42c	113	Bloodstone . . . . .	16a	94
Amethyst . . . . .	14g	93	Boart . . . . .	1f	78
Analcime . . . . .	29g	105	Boracite . . . . .	37d	110
Anatase . . . . .	14a	92	Borax . . . . .	37c	110
Andalusite . . . . .	26b	101	Bourmonite . . . . .	7d	84
Andrewsite . . . . .	38g	111	Braunite . . . . .	9f	89
Anglesite . . . . .	36c	108	Brochantite . . . . .	35g	109
Anhydrite . . . . .	35b	108	Bronzite . . . . .	22h	99
Ankerite . . . . .	20g	97	Brookite . . . . .	14a	92
Anorthite . . . . .	28g	104	Brucite. . . . .	10d	88
Antimonite . . . . .	6e	83			
Antimony. . . . .	2g	77	Cacholong . . . . .	15e	95
Apatite. . . . .	40b	112	Cairngorm . . . . .	14f	93
Apophyllite . . . . .	24f	100	Calaité . . . . .	38g	111
Aquamarine . . . . .	30a	104	Calamine . . . . .	19h	97
Aragonite . . . . .	17a	96	Calcite . . . . .	18e	96
Argentite . . . . .	3d	80	Calcouranite . . . . .	39c	112
Arsenic. . . . .	2g	76	Caledonite . . . . .	37c	110
Arsenolite . . . . .	15f	95	Calomel . . . . .	9b	86
Asbestos . . . . .	24c	99	Carbonado . . . . .	1f	78
Astrophyllite. . . . .	28c	103	Carbuncle . . . . .	26f	101
Atacamite . . . . .	9d	87	Carnelian . . . . .	16f	95
Augite . . . . .	21g	99	Cassiterite . . . . .	11f	91
Automolite . . . . .	10e	88			
Avanturine . . . . .	13e	93	Cat's-eye . . . . .	9e, 13f	89
Axinite . . . . .	33d	107	Celestine . . . . .	35d	108

	CASE	PAGE		CASE	PAGE
Cerargyrite . . . . .	8h	86	Dolomite . . . . .	20d	97
Cerussite . . . . .	18b	96	Dyscrasite . . . . .	3a	80
Cervantite . . . . .	15h	95	Dysluite . . . . .	10e	88
Chabasite . . . . .	31b	105	Edingtonite . . . . .	29g	105
Chalcanthite . . . . .	35g	109	Eisenkiesel . . . . .	13g	93
Chalcedony . . . . .	15b	94	Electrum . . . . .	2e	75
Chalcopyllite . . . . .	37h	111	Embolite . . . . .	8h	86
Chalcopyrite . . . . .	5b	84	Emerald . . . . .	29c	104
Chalcotrichite . . . . .	10c	88	Emery'. . . . .	9f	90
Chalybite . . . . .	20h	97	Enstatite . . . . .	22h	99
Chessylite . . . . .	21d	98	Epidote . . . . .	27c	103
Childrenite . . . . .	40a	112	Epsomite . . . . .	36h	109
Chloanthite . . . . .	3c	80	Erinite . . . . .	37h	111
Chlorargyrite. . . . .	8h	86	Erubescite . . . . .	5e	84
Chlorites . . . . .	32e-h	105	Erythrite . . . . .	38d	111
Chromite . . . . .	10g	89	Essonite . . . . .	26e	102
Chrysoberyl . . . . .	9e	89	Euclase. . . . .	30b	104
Chrysocolla . . . . .	25c	101	Eudialyte . . . . .	34d	108
Chrysolite . . . . .	22f	98	Felspar. . . . .	28g	103
Chrysoprase . . . . .	16a	94	Fergusonite . . . . .	34h	108
Churchite . . . . .	38b	111	Fibrolite . . . . .	26d	102
Cinnabar . . . . .	3h	81	Fiorite . . . . .	15c	95
Cinnamon-Stone . . . . .	26e	102	Flint . . . . .	15b	94
Clays . . . . .	30c	105	Fluellite . . . . .	9c	86
Clinochlore . . . . .	32f	106	Fluor . . . . .	7e	86
Clinoclase . . . . .	37h	111	Franklinite . . . . .	10h	89
Coal . . . . .	41a	113	Gadolinite . . . . .	22g	99
Cobalt-Glance . . . . .	6g	83	Galena . . . . .	4e	81
Cobaltine . . . . .	6g	83	Garnet . . . . .	26e	102
Columbite . . . . .	34g	108	Glaucodote . . . . .	6h	83
Connellite . . . . .	37b	110	Göthite. . . . .	12a	90
Copper. . . . .	1a	73	Gold . . . . .	2b	74
Copper-Glance . . . . .	3e	81	Graphite . . . . .	1h	78
Copper-Pyrites . . . . .	5f	84	Greenockite . . . . .	5a	81
Corundum . . . . .	9f	89	Grey Copper Ore . . . . .	7a	84
Cotterite . . . . .	14f	93	Gypsum . . . . .	36f	108
Crocidolite . . . . .	24a	99	Hæmatite . . . . .	11a	90
Crocoisite . . . . .	35a	108	Haidingerite . . . . .	38b	110
Cromfordite . . . . .	22d	98	Halloysite . . . . .	30c	105
Cronstedtite . . . . .	31e	106	Harmotome . . . . .	31d	105
Crookesite . . . . .	5c	82	Hauerite . . . . .	5d	82
Cryolite. . . . .	9c	86	Hausmannite. . . . .	10h	89
Crystal. . . . .	14b	92	Häütyne. . . . .	34b	107
Cuprite. . . . .	10a	87	Heavy Spar . . . . .	36a	108
Cuprouranite . . . . .	39d	112	Heliotrope . . . . .	16a	94
Danaite. . . . .	6h	83	Helvine . . . . .	31h	106
Danalite . . . . .	31h	106	Hemimorphite . . . . .	25b	101
Danburite . . . . .	34a	107	Heulandite . . . . .	32c	105
Datholite . . . . .	34a	107	Hiddenite . . . . .	23a	99
Diamond . . . . .	1f	78	Hornblende . . . . .	23d	99
Diaspore . . . . .	12b	91			
Dichroite . . . . .	28a	103			
Dioptase . . . . .	22f	98			

	CASE	PAGE		CASE	PAGE
Hornsilver . . . . .	8h	86	Malachite . . . . .	22b	98
Hornstone . . . . .	15a	94	Manganite . . . . .	12c	91
Humite . . . . .	22g	98	Marcasite . . . . .	6h	82
Hyacinth . . . . .	13b	92	Margarite . . . . .	32h	106
Hyalite . . . . .	16f	95	Matlockite . . . . .	9c	87
Hydrophane . . . . .	16g	95	Meerschaum . . . . .	23g	100
Hypersthene . . . . .	22h	99	Melaconite . . . . .	10c	88
			Melanterite . . . . .	35e	109
Iceland Spar . . . . .	18e	96	Mendipite . . . . .	9c	87
Idocrase . . . . .	25e	102	Mercury . . . . .	2f	76
Ilmenite . . . . .	11d	90	Mesitite . . . . .	20h	97
Iridosmine . . . . .	2f	76	Mesclite . . . . .	29e	105
Iron . . . . .	2f	75	Mica . . . . .	28a	103
Iron-Pyrites . . . . .	5d	82	Microcline . . . . .	29a	104
			Millerite . . . . .	5b	81
Jacynth . . . . .	13b	92	Mimetesite . . . . .	40g	112
Jade . . . . .	24d	99	Mispickel . . . . .	6h	83
Jadeite . . . . .	27a	102	Mocha Stone . . . . .	16e	94
Jargon . . . . .	13b	92	Molybdenite . . . . .	6c	82
Jasper . . . . .	13g	93	Muscovite . . . . .	28d	103
Jordanite . . . . .	8d	85			
			Nagyagite . . . . .	5c	82
Kaolinite . . . . .	30b	105	Natrolite . . . . .	30g	105
Kieserite . . . . .	36h	109	Nepheline . . . . .	28f	103
Kreittouite . . . . .	10e	88	Nephrite . . . . .	24d	99
Kyanite . . . . .	26c	101	Nickel-Glance . . . . .	6g	83
			Nickeline . . . . .	3a	80
Labradorite . . . . .	28h	104	Nitratine . . . . .	37d	110
Lanarkite . . . . .	36f	108	Nitre . . . . .	37d	110
Langite . . . . .	35g	109			
Lapis Lazuli . . . . .	34h	107	Oligoclase . . . . .	27e	104
Laumontite . . . . .	29h	105	Olivenite . . . . .	37e	111
Laurite . . . . .	6d	83	Olivine . . . . .	22f	98
Lazulite . . . . .	39b	112	Onyx . . . . .	16c	94
Lead . . . . .	2f	75	Opal . . . . .	16f	95
Leadhillite . . . . .	37c	110	Orangite . . . . .	13c	92
Lepidolite . . . . .	28e	103	Orpiment . . . . .	6g	83
Lepidomelane . . . . .	28c	103	Orthoclase . . . . .	27e	104
Lettsomite . . . . .	25h	109	Osteolite . . . . .	40d	112
Leucite . . . . .	28e	103			
Libethenite . . . . .	37e	111	Parisite . . . . .	22d	98
Lievrite . . . . .	27a	102	Pennine . . . . .	32e	105
Limnite . . . . .	12f	91	Pentlandite . . . . .	4h	81
Limonite . . . . .	12d	91	Periclase . . . . .	10c	88
Linarite . . . . .	37b	109	Pericline . . . . .	29b	104
Liroconite . . . . .	40a	112	Peridot . . . . .	22f	98
Ludlamite . . . . .	37g	111	Perofskite . . . . .	34c	108
Ludwigite . . . . .	37c	110	Pharmacolite . . . . .	38b	110
Lydian-Stone . . . . .	15a	94	Pharmacosiderite . . . . .	38d	111
			Phenakite . . . . .	22e	98
Magnesite . . . . .	20d	97	Phlogopite . . . . .	28a	103
Magnetic Iron Ore . . . . .	10f	88	Phosgenite . . . . .	22d	98
Magnetic Pyrites . . . . .	5e	84	Phosphorite . . . . .	40d	112
Magnetite . . . . .	10f	88	Pitchblende . . . . .	10h	89

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Plasma . . . . .	16a	94	Serpentine . . . . .	25a	101
Platinum . . . . .	2f	75	Silver . . . . .	1c	74
Pleonasto . . . . .	10f	88	Skutterudite . . . . .	3c	80
Plumbago . . . . .	1h	79	Smaltine . . . . .	3b	80
Pollucite . . . . .	29h	105	Soapstone . . . . .	23g	100
Porpezite . . . . .	2c	75	Soda Nitre . . . . .	37d	110
Potato Stone . . . . .	14c	93	Sodalite . . . . .	31h	106
Prase . . . . .	13e	93	Sombrierite . . . . .	40d	112
Prehnite . . . . .	30e	105	Spathic Iron Ore . . . . .	20h	97
Proustite . . . . .	8b	84	Spartalite . . . . .	10c	88
Psilomelane . . . . .	12f	91	Specular Iron . . . . .	11b	90
Pyrargyrite . . . . .	8a	84	Spheno . . . . .	34d	108
Pyrites . . . . .	5d	82	Spinel . . . . .	10e	88
Pyrolusite . . . . .	11e	91	Spodumene . . . . .	23a	99
Pyromorphite . . . . .	40e	112	Star-Stone . . . . .	9h	90
Pyrope . . . . .	26h	102	Staurolite . . . . .	26c	101
Pyrophyllite . . . . .	30d	105	Steatite . . . . .	23g	100
Pyrosmalite . . . . .	31h	106	Stephanite . . . . .	5h	84
Pyrrhite . . . . .	34h	108	Stibnite . . . . .	6e	83
Pyrrhotine . . . . .	5e	84	Stilbite . . . . .	32a	105
Quartz . . . . .	14b	92	Stolzite . . . . .	33g	108
Quicksilver . . . . .	2f	76	Stream Tin . . . . .	13a	92
Realgar . . . . .	6c	83	Strontianite . . . . .	18b	96
Redruthite . . . . .	3e	81	Sulphur . . . . .	1e	77
Rhabdophane . . . . .	38b	111	Susannite . . . . .	37c	110
Rhedicite . . . . .	37c	110	Sylvanite . . . . .	6d	83
Rhodochrosite . . . . .	19h	97	Sylvine . . . . .	8f	85
Rhodonite . . . . .	24e	100	Talc . . . . .	23g	100
Ripidolite . . . . .	32h	106	Tellurium . . . . .	2h	76
Rock Crystal . . . . .	14b	92	Tennantite . . . . .	7b	84
Rubellite . . . . .	33a	107	Tephroite . . . . .	22f	98
Ruby . . . . .	9h	90	Tetrahedrite . . . . .	7a	84
Ruby Copper . . . . .	10a	87	Thorite . . . . .	13c	92
Rutile . . . . .	13d	92	Tile Ore . . . . .	10b	88
Sal-Ammoniac . . . . .	8g	86	Tin . . . . .	2f	75
Salt . . . . .	8f	85	Tin Stone . . . . .	11f	91
Saltpetre . . . . .	37d	110	Topaz . . . . .	25c	101
Samarskite . . . . .	34g	108	Touchstone . . . . .	15a	94
Sapphire . . . . .	9h	90	Tourmaline . . . . .	33a	106
Sapphire d'eau . . . . .	28a	103	Tridymite . . . . .	14b	92
Sarcolite . . . . .	25g	102	Tscheffkinitite . . . . .	34f	108
Sard . . . . .	16a	94	Turgite . . . . .	12d	91
Sardonyx . . . . .	16b	94	Turquoise . . . . .	38g	111
Sassoline . . . . .	15g	95	Ullmannite . . . . .	6g	83
Scapolite . . . . .	25g	102	Uranocircite . . . . .	39c	112
Scheelite . . . . .	33g	108	Uwarowite . . . . .	26h	102
Scolecite . . . . .	29f	105	Valentinite . . . . .	15g	95
Scorodite . . . . .	38e	111	Vanadinite . . . . .	29e	112
Scovillite . . . . .	38b	111	Vermiculite . . . . .	32e	106
Selenite . . . . .	36g	108	Vivianite . . . . .	38c	111
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Wad . . . . .	12h	91	Wood Tin . . . . .	13a	91
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Waringtonite. . . . .	35g	109	Wurtzite . . . . .	5a	81
Wavellite . . . . .	38f	111			
Whewellite . . . . .	39h	112	Xanthoconite. . . . .	8e	85
Willemite . . . . .	22e	98			
Witherite . . . . .	18a	96	Zeolites . . . . .	30e-32d	105
Wolfram . . . . .	33h	108	Zincite. . . . .	10c	88
Wollastonite . . . . .	24e	100	Zircon . . . . .	13b	92

THE END.













